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Motorcyle Safety — A review of information gathered from overseas: January, 1978

M.R. Wigan

AUSTRALIAN ROAD RESEARCH BOARD
RESEARCH REPORT

APPLICATION SUMMARY

Australian Road Research Board

THE PURPOSE OF THIS REPORT ....

— *is to collate current work on motorcycle safety brought into focus by a series of visits in U.S. and U.K.*

— *is to summarise and add material gathered as a result of these visits to provide a useful context with adequate referencing*

THIS REPORT SHOULD INTEREST ....

— *Road safety and education workers and researchers*

— *Standards Association Committee Members concerned with helmets and visors*

— *ATAC Committee Members concerned with vehicle design, use, and education*

AS A CONSEQUENCE OF THE WORK REPORTED, THE FOLLOWING ACTION IS RECOMMENDED ....

— *Maintain a watching brief on motorcycle safety and evaluation issues*

— *Participation in the official Committees concerned*

— *Selective follow-up in greater depth in some areas covered by this report*

— *Continued liaison with overseas contacts to maintain level of reference awareness*

RELATED CURRENT ARRB RESEARCH ....

812: Motorcycle Safety

293: Accident Economics

155: Transport Statistics

913: Standards Association Support

CUT OUT INFORMATION RETRIEVAL CARD ....

AUSTRALIAN ROAD RESEARCH BOARD

0013489

TITLE: MOTORCYCLE SAFETY: A REVIEW OF INFORMATION GATHERED FROM OVERSEAS: JANUARY, 1978

KEYWORDS: Motorcycle/safety/crash helmet/driving licence/test/~~moped~~/Legislation/driver training/braking/specification (Standard)/report of visit/USA/United Kingdom/accident/vehicle handling

SUMMARY: This report collates the motorcycle safety aspects which came up during several days of an overseas study journey in January 1978, and is substantially extended by embodying in the text much of the material subsequently collected by or sent on to the author. The subjects covered include motorcycle dynamics, wet weather and antilock braking, accident analysis, education, training, licencing legislation, motorcycle visibility, helmet performance, helmet and visor standards, U.S. motorcycle and moped legislation, and moped issues.

This approach has been adopted due to the scattered and inaccessible nature of many of the sources, and the consequent value of a reasonable broad and up-to-date coverage of the material and findings in context. The sections of this report concerned specifically with visors and helmets have already been drawn upon in connection with Standards issues.

REFERENCE: WIGAN, M.R. (1979). Motorcycle Safety: A review of information gathered from overseas: January, 1978. Australian Road Research Board. Research Report ARR 91.

*Non IRRD Keywords

Australian Road Research Board
Research Report ARR No. 91

MOTORCYCLE SAFETY —
A REVIEW OF INFORMATION GATHERED FROM OVERSEAS: JANUARY, 1978

by

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April, 1979

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CONTENTS

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1. PERTH, WESTERN AUSTRALIA

1.1 CHAMBER OF COMMERCE (MOTORCYCLE DIVISION) MOPED DEVELOPMENT

Initial contact was made with R.J. Lyons of Alron Industries. This organisation was the only domestic manufacturer, and manufactured dirt bikes until a switch over to Rickman complete frame kits (less engine) was made. Lyons has paid for local ADR 33 tests on Motobecane mopeds and obtained satisfactory results - technically these mopeds could not meet ADR 33 due to testing procedure complications, especially the ADR requirement of braking tests with clutches disengaged: this is not possible with the automatic clutches fitted to the Motobecane mopeds. However the braking performance is more than adequate. Recent variations in the application of ADR 33 to small product numbers, and other possible revisions (House of Representatives 1978) may solve these problems. Mopeds in Western Australia have been on sale for five or six years and over 300 have been sold. No accidents to the several hundred Motobecanes have yet occurred which required anything more than flasher replacement, as monitored by spare parts sales. A complete range of the population buys mopeds, with no particular emphasis on young male drivers - mopeds also appear to be sold to owners of large motorcycles as a second (or even third) machine.

1.2 ROAD TRAFFIC AUTHORITY

Ian Smith, Research Officer advised that a Draft Act was proceeding** during 1978 under the title "Road Authority Amendment Act". Some of the items expected to be included are:

(a) Licence age reduction from 17 to 16 for mopeds.

(b) Definition of a moped to include pedals.

(c) A required one-day post licencing course to be taken within six months of first licence issue - will be run by the National Safety Council which operates the Mount Lawley Centre.

(d) Special powers might be included for certain licences to be issued earlier conditional on the satisfactory completion of specified training.

It should be noted that the relevant Western Australian Road Traffic Acts are enabling Acts, and the regulations and their detailed drafting are the responsibility of the Road Traffic Authority in consultation. This is the point at which most of the arguments and controversies are to be resolved.

Computerisation of Western Australian accident records is due for the end of August, when the records are to be on-line on the MRD Cyber 72*. The accident records are to be linked with the vehicle registration file. This is a joint exercise between Main Roads Department and Road Traffic Authority, and the plans include a later link to the driver's licence files for "any casualty and all accidents with above $100 per property damage". The plan is to up-date all 1976 and 1977 data in the first stage. Enforcement data is also to be linked in and this of course presents considerable security difficulties. Presently, Western Australia sends tapes cleared of such necessarily secure data to the Australian Bureau of Statistics every quarter. Smith emphasised that copies could readily be duplicated to ARRB if requested.

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*Western Australian Main Roads Department Control Data Cyber 72 model.

**This Act was passed, but Regulations under the Act ~~were~~ still being sorted out in March 1979.

A before and after study of the new licensing requirements for two-wheeled vehicles is tentatively budgeted at a cost of $150,000 and is expected to produce useful results on graded licensing and the associated training schemes once they are undertaken.

2. TRANSPORT AND ROAD RESEARCH LABORATORY, U.K.

2.1 P.M.F. WATSON, VEHICLES DIVISION

Peter Watson stated that the next target of work at TRRL would be lower leg crash impact protection. Current activities on braking are aimed mainly at resolving patent and production difficulties for antilock brakes and at documenting and attacking slow wet weather reaction times of disc brakes. Chest pad protection integrated with the motorcycle tank has been studied. John Whittiker was responsible for the first initial experiment, aimed at converting a 48 km/h head-on impact to a 13 km/h forward dummy speed *without* rotational momentum being imparted to the dummy. User acceptability is presently a problem, but this may be in hand with the first re-design. Tests using anthropometric dummies indicate that the tank shape strongly affects the ejection path and any tank with a rear hump pushes the dummy high in the air with a strong rotational movement. Consequently chest pad and tank must be treated as a single system to stop submarining or the imparting of high rotational velocities. Watson mentioned that in the U.K. Department of Transport, central motorcycling engineering regulation is handled by Ted Haynes and Len Baxter to whom enquiries on the regulatory issues should be addressed. Wet weather braking has so far been the subject only of an initial investigation and the primary result was that the experimental conditions were still too variable to be able to make any useful measurements. A Kawasaki Z650 is being used and the initial braking tests have been carried out with standard discs, stainless steel discs, and drilled discs, and also a specially cut surface-slotted disc machined by ART of London, (See section 4.2).

Antilock braking systems are now at a suitable stage for commercial interests to take up for production. An advanced stage of negotiation has been reached on several commercial avenues. These include Mullard for the electronics, as they have been the contractors for the entire development process, and another firm for the brakes themselves. There are two application objectives:

1. Retrofit system production.
2. Original equipment manufacture and supply.

Current application plans include fitting antilock calipers to up to six bikes from Police fleets for extended trials by September 1978, with a much bigger pre-production trial batch for September 1979. Contracts over 2-3 years with both firms are currently contemplated. A description of present test results is given by Watson (1976), and Figs 1,2 show the form and mode of operation of the prototype system. The key to the diagrams is also drawn from TRRL (1975) as follows:

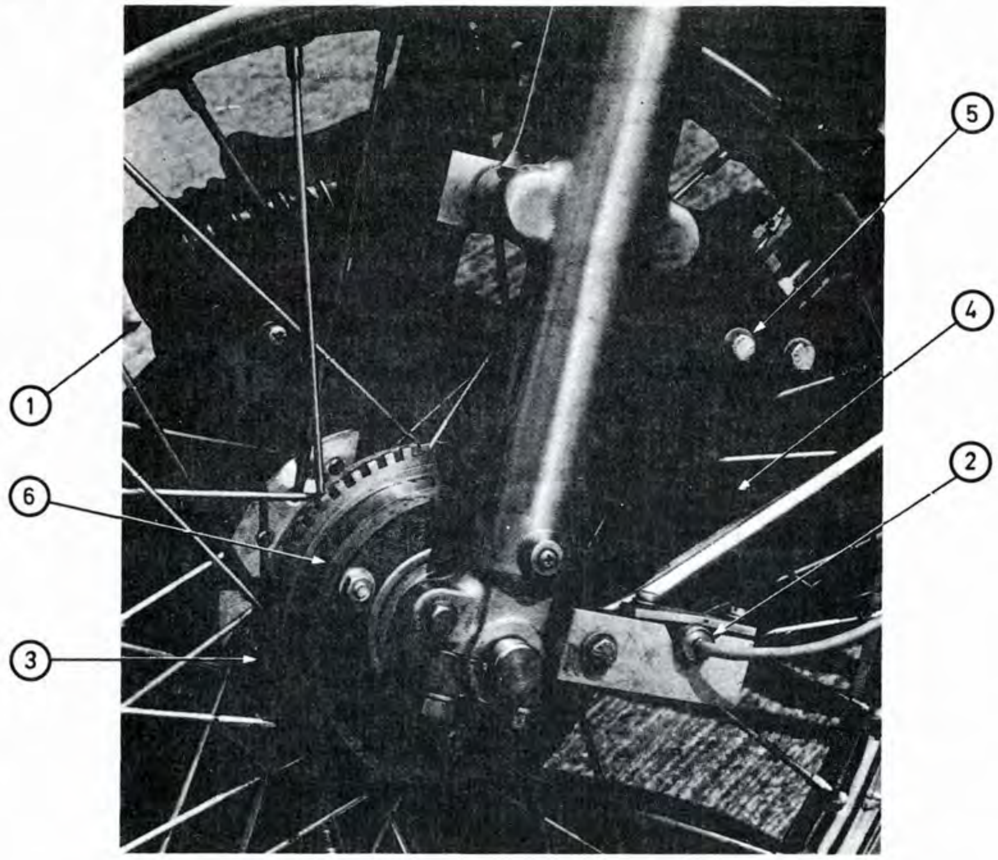
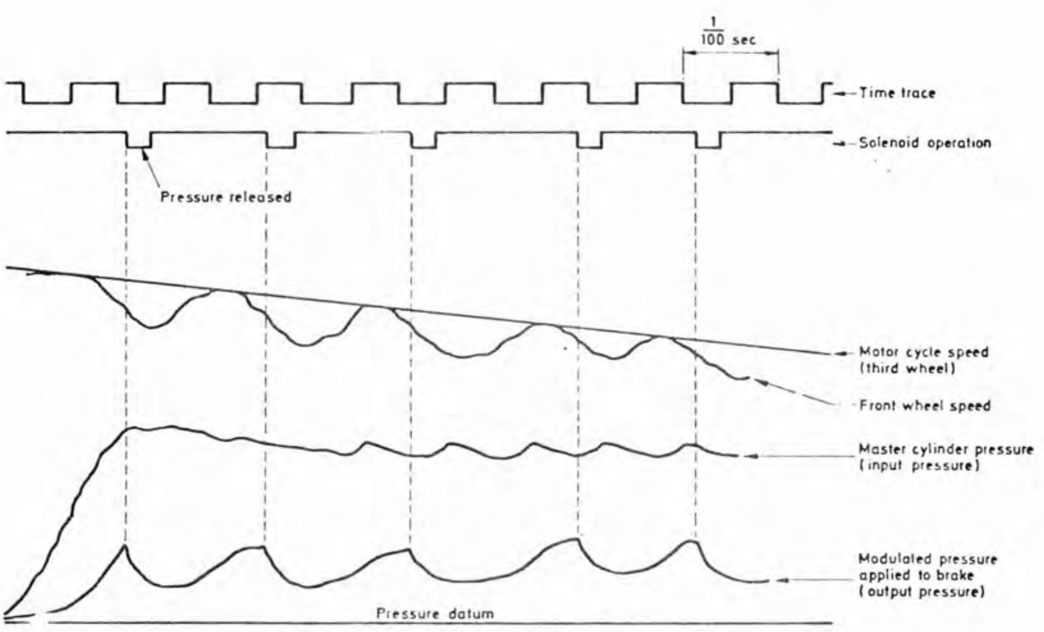


FIG. 1 FRONT WHEEL FITTED WITH ANTILOCK SENSOR AND CALIPER

(Source: TRRL (1975))



CYCLE OF OPERATION

FIG. 2: TRRL PROTOTYPE ANTILOCK MOTORCYCLE BRAKE

(Source: TRRL (1975))

"The system is suitable for machines which are fitted with hydraulically operated disc brakes[1]. The speed of the braked wheel is continuously monitored by the transducer[2] and toothed wheel[3] and whenever the wheel decelerates at a rate which is greater than a predetermined setting (usually 1g) due to over-braking, a logic circuit on the electronic control panel mounted under the saddle releases the applied brake pressure through a solenoid valve[4]. This allows the wheel to recover its speed at which point the solenoid valve closes and braking is reapplied at a rate which depends on the degree of slipperiness of the road surface i.e. slowly, if slippery; quickly if relatively non-skid. This sequence of operations is repeated until the motorcycle comes to rest as in the diagram below. Master cylinder pressure is maintained during braking by a simple pump in the block[5] driven from the braked wheel by a three-lobed cam[6] thus making the hydraulic system completely self-contained and applicable to any motorcycle equipped with hydraulic disc brakes."

For handling standards I was referred to David Weir at Systems Technology Incorporated who was quoted by Watson as saying that to begin to draft such Standards would need at least five years of further work.

SCPR* has a current TRRL contract to measure the exposure, conditions, and the risk rate needed to assess motorcycle safety factors. Pilot studies indicated that four falls from the machine resulted in a casualty accident only once and that for every nine driver-only accidents, the tenth was a casualty accident for someone else. The original aim was to start and run this contract between January and December, 1974. Currently the schedule runs from 9/76 to 8/77 with a lower level extension to 9/78. The response rate to questionnaires is currently running at above 70 per cent.

The user interest in wet weather braking performance has become so marked that a magazine commissioned a series of reasonably consistent tests on both brake pad materials and disc and brake pad machining (Robinson, 1978*a*, *b*). The grooving of disc pad materials showed notable and worthwhile gains - in agreement with the results reported by Honda (Wigan 1977). The most interesting findings were that the ART machining procedures were effective, while subject to many qualifying reservations of the type quoted by TRRL. The successful second stage of this program is reported by Wigan (1978*b*)

J.C. Tanner has recently completed a review of motorcycle and moped ownership and use on both national and international bases (Tanner 1977).

The distinctions between moped and motorcycle ownership is most apparent in Figures 3 and 4, where Australia is low in all types of motorcycles/head, and effectively zero in terms of mopeds/head in 1974, while comparisons of OECD figures for 1974 corrected to motorcycles as *distinct* from mopeds places Australia third highest in the world in motorcycles/head at that date, and barely 5 per cent lower than the highest rate recorded.

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* Social, Community, and Planning Research. 5 Regent Terrace, London N6. U.K.

	MINIMUM AGE		WHETHER MOPEDS REQUIRE		
	Moped	Other Motorcycle	Driving Licence	Vehicle Licence	Insurance
AUSTRIA	16	18	No	Yes	Yes
BELGUIM	16	18	No	No	Yes
DENMARK	15	18	No	No	Yes
FINLAND	15	16/18	No	No	Yes
FRANCE	14	16/	No	No	Yes
WEST GERMANY	15/16	18	Yes/No	No	Yes
GREAT BRITAIN	16	17	Yes	Yes	Yes
IRELAND	16	16/18	Yes	Yes	Yes
ITALY	14	16/18	No	No	No
NETHERLANDS	16	18	No	No	Yes
NORWAY	16		No	No	No
SPAIN	16	16	Yes	No	No
SWITZERLAND	14	18	Yes	Yes	Yes
CANADA	14/16	16	Yes	Yes	Yes
JAPAN	16	16	Yes	No	Yes
NEW ZEALAND	15	15	Yes		Yes

TABLE 1: MOPED REGULATIONS AND DEFINITIONS

(Source: Tanner (1977)).

ESSENTIAL MOPED REGULATIONS IN EUROPE					
	CAPACITY	PERMISSABLE SPEED LIMIT KM/H	MAXIMUM NOISE LEVEL DB	HORSEPOWER RATING PS	ADDITIONAL SPECIFICATIONS
BELGIUM	UNIFORMLY NOT MORE THAN 50 CC	40	73		Pedals
DENMARK		30	73	1.2	Motor Throttle
WEST GERMANY		25	70		Pedals, Throttle Maximum revs. 4000 RPM
		40	73		
ENGLAND		UNRESTRICTED	77		Pedals
FINLAND		40	75	1.5	Maximum vehicle wgt. 55 KG
FRANCE		45	73		Pedals
HOLLAND		40	73		Pedals
ITALY		40	81	1.5	Motor wgt. maximum 10 KG
NORWAY		50	75	2.5	
AUSTRIA		40	73		
SWEDEN		30	75	1	Throttle
SWITZERLAND		30	70	0.8	Pedals Vehicle wgt. maximum 42 KG
SPAIN		40	80		Pedals Vehicle wgt. maximum 55 KG
YUGOSLAVIA		40	78		

TABLE 2: MOPED REGULATIONS AND DEFINITIONS

(Source: Bureau Permenant International des Constructeurs de Motorcycles (1976)).

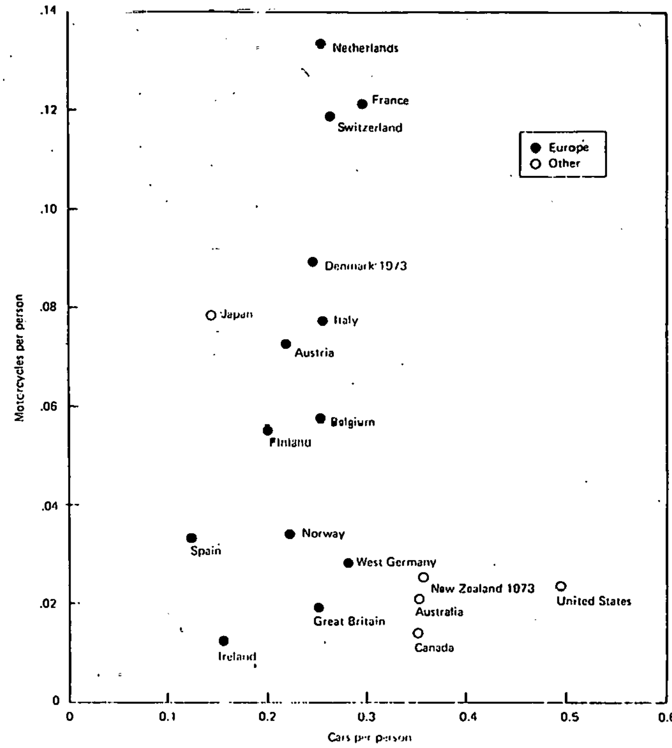

FIG. 3: MOTORCYCLE AND CAR OWNERSHIP IN VARIOUS COUNTRIES 1974

(Source: Tanner (1977)).

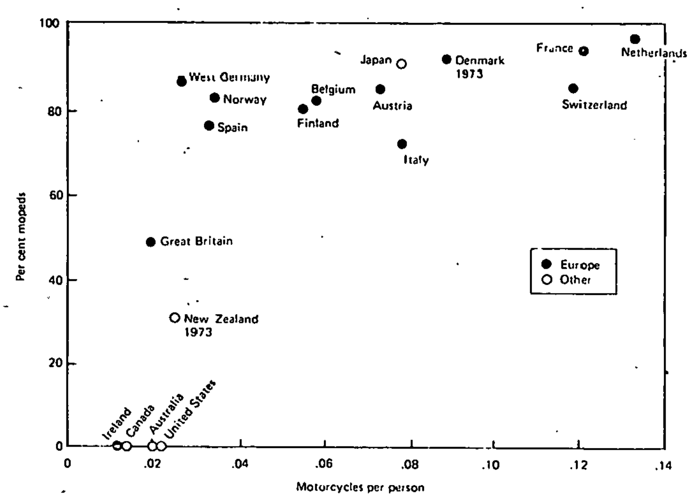

FIG. 4: MOPED AND OTHER MOTORCYCLE OWNERSHIP IN VARIOUS COUNTRIES 1974

(Source: Tanner 1977).

Tanner also finds that the ratio of cars to motorcycles in the U.K. is remarkably stable over the whole range of household incomes at about 0.07.

Figure 5 shows how the moped dimension also discriminates very well between the motorcycle mileage rates for different countries: Australia would be on the y-axis in company with the U.S.A. at these dates. Figure 6 is a graphic illustration of theAustralian growth in motorcycle registrations up to the peak year of 1974: since then motorcycle sales have seen a steep decline (Thoresen and Wigan 1979). Tanner observes that only the restrictive legislative treatment of mopeds in countries with presently low moped ownership is stopping rapid growth in this mode of transport. The events in the U.S. since 1974 have supported this view. Table 1 shows that the lowest 1974 motorcycle ownership is in Britain and Ireland (0.016) where licencing and driving licences are needed for mopeds, together with a minimum age of 16: in France neither are needed and the minimum age is 14, with the far higher ownership rate of 0.100. Table 2 extends the coverage of vehicle definitions.

An interesting summary regression equation was developed on the basis of U.K. annual incomes for 1972/3 and 1974 car ownership:

$$\begin{aligned}\text{Motorcycles/person} = 0.019 &- 0.0000122 \text{ Income} - 0.0002525 \text{ persons/hectare}\\ &- 0.0000287 \text{ Rainfall}^* + 0.00283 \text{ Average temperature}\\ &+ 0.0890 \text{ cars/person}^*\end{aligned}$$

(R = 0.88)

where Rainfall is mm average from 1901-1930, (all variables significant) temperature is in ^{o}C as an average daily mean from 1901-30.

A contract for external work is also held by the Simon Laboratories, Manchester University. Roe and Thorpe have completed an initial round of work (1976) on motorcycle stability, and an initial report has been completed. The discussion then turned to leg protection.

Air bags have been tried, and for frontal collision they work reasonably well, but they must have something to react against: consequently it seems necessary to integrate a full fairing into the system. The chest pad seems to be a more effective line of work, and the new version now being developed is likely to be substantially more acceptable.

Current work on braking is concentrated on wet weather reaction time on disc brakes. The Honda Motor Co. Ltd. (1978) have been concentrating on wet weather *efficiency* factors, while TRRL efforts are aimed mainly at reducing the *lag in response* of disc brakes in wet weather. The indications of the Phase I tests are that drilling the discs may even reduce braking efficiency and increase reaction time, but the primary problem of the technique of the measurement masks all but the major effects. The program as a whole was due for completion in February 1979, and has been carried out using a bike with continuous water feed. In the third phase, ground and wheel water sprinklers must be used, and will be. An objective of Phase II is to obtain correlations between some simple experimental technique using sprinklers and practical tests carried out in heavy rain. The procedure should then provide a good basis for a "design rule" approach. Honda (1978) now report that excellent correlations have been obtained in the course of their wet weather braking efficiency program. Phase I results at TRRL are generally restricted to testing from 30 mph. From this speed the stopping performance of any of the different forms of machine discs seem to be similar, although the specific issue being assessed was the definite lag on initial application of the brake in the wet. ART (Applied Racing Techniques)

* Items are the most important, and the equation indicates a degree of substitutability between motorcycles and cars.

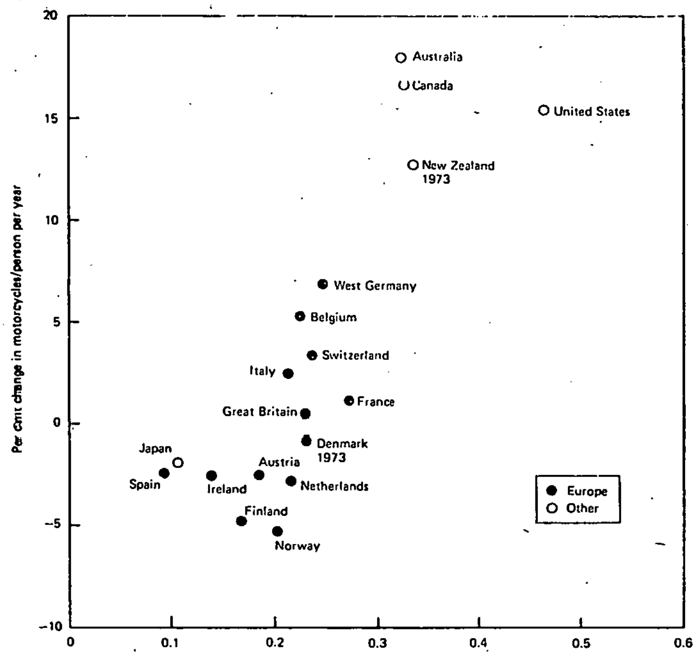

FIG. 5: GROWTH OF MOTORCYCLE OWNERSHIP FROM 1969 TO 1974 IN RELATION TO LEVEL OF CAR OWNERSHIP.

(Source: Tanner 1977).

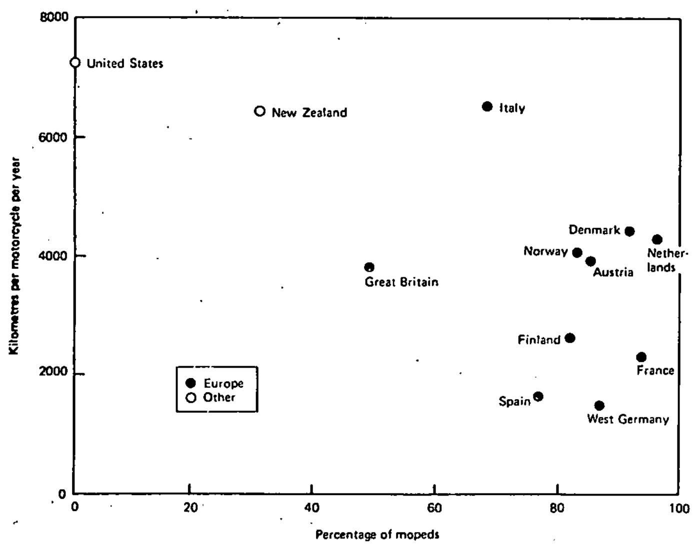

FIG. 6: KM/MOTORCYCLE RELATED TO PER CENT OF MOPEDS IN VARIOUS COUNTRIES 1972/3/4.

(Source: Tanner 1977).

of Wimbledon, London, offer a proprietary slot machining process which they are confident demonstrates significant improvement in braking from higher speeds than 48 km/h. The main cause for uncertainty in the conclusions to be drawn from the tests so far is thought to be the period of time taken to bed in both disc and pad surfaces. Phase II testing at TRRL covered this, and included testing on materials for discs and also included shot blasted disc surfaces. TRRL agree with the ART view that it takes between 1000 and 4000 miles for braking performance to stabilise. In order to set up precise grounds for these measurements surface testing of discs were made with the surprising initial result that the Talysurf is not good enough for the task. The polishing action as it takes place is, of course, distributed across both disc and pad and approximate figures so far are a 15 per cent polishing action on the disc for 100 per cent polishing action on the pads. These also approximate to the magnitudes of the effects of polishing on lag times in use, but apply only to conventional (organic) pad materials.

Some comments on motorcycle ownership per head arose in discussion of Wigan and Thoresen (1977) for all Australia. A cautionary note was sounded on forecasting bases until local goegraphical variations could be better explained. These also showed up in U.K. county level ownership analyses.

Fieldon, the Director-General of the British Standards Institution, is most keen to develop standards for antilock braking. U.S. contacts suggested including Jack Miennert and Dr. Jeffrey Bluestein at the AMF Harley Davidson Laboratories in Milwaukee. AMF have been actively concerned with antilock testing and experimental safety motorcycle program in the U.S. (Bartol *et al.* 1975) (Miennert, R.J. (1974)).

We then proceeded to the TRRL test track and the antilock equipped motorcycle was demonstrated. This machine is a Norton 850 cc "Comando" fitted with independent Mullard-TRRL antilock systems front and rear with no cross-linking between the systems. It was further pointed out that cross-linking between the front and rear brakes could lead to legal difficulties due to the restrictive legislative drafting in some countries and States. It should be noted that Australia is one such country. This motorcycle is fitted with fixed side skids and has been used extensively. It was the subject of a recent U.S. appraisal carried out by Dr. David Weir at Systems Technology International at Los Angeles as part of an NHTSA project. Jeff Meades accompanied the machine to the U.S. for this initial appraisal. The basic design of the antilock system is of a small idler pump driven by a tooth gear or a machined disc edge, with the mechanism to trigger a pressure by-pass being actuated approximately 6 times per second at a specified rotational angle. This approach is therefore based on the first derivative of the angular rotation, and clearly has a fundamental problem if the machine is ridden on sheet ice or surfaces with near-zero friction as there must be some marginal residual friction operative to complete the action of the antilock caliper. Needless to say however there are other problems involved in such circumstances, and in practice on wetted polished brick or gravel surfaces with an extremely low coefficient of friction, the antilock system works extremely well both front and rear. I rode the machine and carried out crash braking on such surfaces with amazingly stable results. This experiment was repeated at up to 70 mph by Peter Watson, and I proceeded to follow with hard braking while lent over at the maximum angle permitted by the skids on the wetted polished surface. The characteristics of the braking system gave a faint feel of progressive slide and bite of the rear tyre in a totally controllable and confidence building manner.

I can anticipate some psychological problems with riders on antilock equipped motorcycles due to the feeling of extreme stability induced on marginal surfaces. It should further be noted that crash braking over the boundary between a wetted high friction and a wetted low friction surface was handled smoothly and effectively by both front and rear brakes. The subjective view would be that this system should be put into direct commercial development with a view to production when reliability of the production system reached a satisfactory level. This is indeed the TRRL view. However, they reported a surprising lack of interest from brake manufacturers. In contrast, it should be noted that the NHTSA approach (Tenney 1977) commissioned from the Harry Diamond Laboratories is to use a fluidics control system which works on the second derivitive of rotation (or "jerk") and so continues to rotate even if there is no friction whatever. This difference in approach may in practice be no more than the ability to handle the legal definitions of extreme circumstances, and lead to no real difference in performance in use. Early Japanese approaches by JAMA* are summarised by Aoki (1977), and the Motorcycle Brake Working Group of JAMA have recently published a detailed English text of their joint program (JAMA 1978). Honda (1978) report substantial problems of reliability and fail-safe actuation still remain before their antilock brakes could be considered for production.

3. DEPARTMENT OF TRANSPORT, U.K.

3.1 J. RENDELL, ASSISTANT SECRETARY (ROAD SAFETY GENERAL DIVISION).

Mr. Rendell** was responsible for the legislative and associated administrative work on all road safety issues. Primary sources for this Division are the regular Road Accident Statistics Reviews (e.g. DOE 1977). Manufacturers supply to the Department of Transport the size and make of vehicles very swiftly after they are sold. Per hundred million km motorcycles appear to be 25 times as dangerous to their *drivers* as cars are to theirs. The *vehicle* involvement rate is 5:1 as against the 25:1 for driver involvements per hundred million km (See Table 12 of DOE 1977). There is nothing at present available to enable comparisons to be made between vehicles in use and vehicle choice at the point of sale. Rendell confirmed that the SCPR Report (being done for TRRL) would be sent when available and the Loughborough Stage II Report (on motorcycle visibility devices, acceptability, and effectiveness) would also be sent when available. There is no specific measure presently available to act as a "carrot" for participation in training in the U.K. as an incentive to pass the motorcycle test. There is therefore no real personal incentive for training, nevertheless there has however been a rapid rise in demand in recent years. Local Authorities were more specifically led on training responsibilities by the 1974 Road Traffic Act - they have always had the executive responsibility.

The appropriate contact for design and construction interests is the Head of Vehicle Safety and Design at DTP, Phillip Critchley.

The "Think Bike" campaign with its 45 sec. commercial was run in the north-east during Autumn 1976 in two bursts of four weeks. The before and after evaluation suggested that a small reduction in accidents had occurred.

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* Japan Automotive Manufacturers Association Inc.

** With the normal rotation of U.K. Civil Service responsibilities, Mr. Rendell's responsibility ended in September 1978: A Mr. Robbins took over.

It was used again in Birmingham in mid 1977, and the rest of the U.K. during February and March, 1978. The total cost of this publicity program is likely to be in the order of £1 million, and the February to March 1978 series to cost just under half that figure.

During February and March 1978, the theme of "a good rider is trained and not born" was to be pursued with a 60 sec. film screened in 600 cinemas around this country, supplemented by full page advertisements in the motor-cycle press. The main stress will be on the need for skills. The total cost of this supportive campaign is estimated to be £47,000.

3.2 D. POULSON, CHIEF DRIVING INSTRUCTOR.

In the car tests about 55 per cent fail on first presentation, motorcycle riders do rather better at around 40 per cent failure rate at first presentation. This is interesting as riders in the U.K. are permitted to ride motorcycles before they are permitted to drive cars, and it is therefore probable that a smaller amount of road experience is held by the two wheeler drivers. The main causes of failure are inadequate observation to the rear before changes in speed and direction.

3.3 G. NORTH: ROAD SAFETY GENERAL

Other interests than motorcycles are covered by Mr. North, alcohol legislation in particular. ECMT have decided on a new initiative on alcohol and the meeting schedules in 1978 aiming for a report at the end of 1978 was mentioned. The Blernerhasset Report (DOE, 1976) which advocated new legislation on random sampling and experimental testing of alcohol levels by better air bag devices, is still awaiting legislative time in Parliament. The current primary issues for road safety general in this are:

(a) Motorcycle casualties at 20 per cent

(b) Pedestrians at 20 per cent

(c) Drinking driving increases in violations

(d) The repeated failures to approve compulsory seat belt usage in the U.K.

A new Chief Engineer at the Department of the Environment is likely to assist in the development of training. On single track vehicle use, there is no present evaluation of *mobility* - although there is specifically no commitment to policies advocating the removal of single track vehicles from the road. This has been stated in DTP circulars. On pedal cycles DTP has taken no firm position, due mainly to the lack of relevant powers or regulation. It is however a problem in which the DTP involvement is presently solely through a construction and use regulation, and at a minimal level.

ROSPA*, and DTP funding goes to the National Cycle Proficiency Scheme. The only recent development is to consider persuading local authorities to give greater attention to pedal cyclists in traffic engineering measures. Bicycling has rapidly recovered from the recent low point - although not as much as motorcycles - and sales are rising although usage is not necessarily increasing. A Transport White Paper is likely shortly which could perhaps press for greater provision of bicycle *routes* rather than bicycle *ways*. The Department of Transport has promised more dissemination of results on traffic engineering and traffic management for bicycles: although bicycle lighting is one of the few possible areas for special attention in the near future.

* Royal Society for the Prevention of Accidents.

£4½ million has recently been spent on publicity towards Drink and Drive, Seat Belt, and Motorcycle measures. "Think Bike" - a 45 second commercial - has been tried in the North-East of England - and included a before and after study which showed a marginal significance in the application. The North-East England before and after study on "Think Bike" was significant only at the 1 per cent level and indicated about 75 non-injury accidents. "Think Bike" was aimed primarily at *car* users. North is concerned primarily with the liaison with representative groups such as the British Motorcycle Federation, the Motorcycle Action Group, the Institution of Motorcycling, the Motorcycle Association of Great Britain, the Motorcycle Associated Manufacturers, the National Association of Cycle and Motorcycle Agents (the main bodies concerned). The U.K. Government has promised a policy statement on Road Safety which would be in the form of a paper or a consultative paper.

4. MOTORCYCLE SAFETY DEVELOPMENTS IN THE INDUSTRY

4.1 JANUARY MOTORCYCLE SHOW: ROYAL HORTICULTURAL HALLS.

The Manager of Owen Helmets (who manufacture the BowBuilt brand) is on the British Standards Committee for Helmets in the U.K. The recently revised BSI 2495 Standard (2495/77) adopted a slightly different testing procedure to 2495 as initially stated (as 2495/71). Owens subjected helmets from their own production line to the 2495/71 and 2495/77 testing procedures and identical helmets appeared to give a higher quality pass under the new testing procedures than they did under the old. They further commented that the present proposals for ECE (European) helmet standards are for lower impacts than the ruling 2495/77, just as the ISO (International) Standard currently in draft is considered to be a step down from the presently achievable Snell 1975 impact levels and more nearly comparable with Snell 1970. An interesting note on the present BSI helmet Standard maintenance procedures is that six in every batch of 500 must physically pass the Standard before the release of the 500 for sale is permitted. This applies both for 5361 and for 2495/77. Both Standards require labels inside the helmet stating batch, Standard and date, and similar labels must also be attached to the shell inside the lining: a constructive measure which could well be worth drawing to the attention of SAA Helmet Committees now that AS 1698 is a Federal Consumer Standard.

Bob Heath of Walsall is a specialist replacement visor manufacturer and sells a huge range of replacement visors mainly in Lexan polycarbonate material. This material is not perfect and the proprietary materials Hydron I, Hydron II and Hydron MXL are now just becoming available for his manufacturing purposes. Lexan and these new variants all share very high impact resistance levels, but unfortunately they all also scratch very readily. For this reason, amongst others, Bell Helmets in the U.S. at present concentrate on acetate materials for visors, while searching actively for better and more suitable materials. The vexed question of the positive and negative effects of scratches and of tinting on glare are now being approa[illegible] by the Australian Standards Association, and some of the relevant work [illegible] reported by Wigan (1979*a*). One of the primary difficulties with full face helmets which, like so many genuine safety features on motorcycles, are being actively purchased and sought out at higher prices by the user population (Bell Helmets reports now a 50/50 sale split between a full face and other varieties of helmet in spite of the substantially higher cost of full face helmets) is that full face helmets are at present prone to misting up on the visors. Owen's have recently patented a variation of the internal liner which fits over the nose and around the cheek bones and therefore directs moisture laden breath out of the base of the helmet. Figure 7 is a photograph of this device.

FIG. 7: MOISTURE GUARD FOR ANTIFOGGING OF HELMET VISOR.

An alternative approach is to consider the use of Hydron polycarbonate material. Hydron I soaks up air moisture by converting it into a liquid continuous film. This is quite effective until its liquid capacity is reached: unfortunately, when this film becomes fully saturated, the visor simply becomes impossible to see through. Hydron treated visors are also suspected to be subject to premature crazing and embrittlement so this improvement in damp weather visibility and resistance to misting is not gained without cost. Hydron II is claimed to have some degree of scratch resistance and to work on moisture in the air immediately without necessitating an early activation by breathing on it, as does Hydron I. Hydron MXL is aimed directly at increasing scratching resistance.

Manx Motorcycles Ltd. was demonstrating an extremely elegant and straightforward rebuildable wireless wheel design capable of handling tubeless tyres. The wheels are made up of two pressed aluminium sheets fitted and bolted together. Some extremely careful design and development work has been done with British Aluminium on the precise pressing procedures, shaping, radii and materials*. These wheels are now made from NS4 pressings and have proved to be fully compatible with tubeless tyres. The strength of these wheels has very considerably exceeded expectations. Any Standard or Design Rule considered for wireless wheels should take special note of this form of construction in addition ot the COMSTAR aluminium/steel construction adopted by Honda and the cast aluminium and magnesium wheels already widely available. The pace of development here is such that any approach to tyre, rim profile, and wheel construction type and standard, should be approached with caution. Honda have just released two models (CX, CBX) using COMSTAR wheels and tubeless tyres meeting the ISO *draft* Standard (see also Wigan 1977).

The Avon Tyre Company specialises in after market replacement tyres for motorcycles. When their technical representative was asked about matching to machines and the basis for their replacement tyre recommendations, it was stated that the production variations between identical models were very considerable, but that within-model variation was being steadily but slowly reduced by all manufacturers by the tightening of the production tolerances for frames, etc. Consequently Avon claim that the tyre recommendations for different models cover variations in suitability far less than the variations in suitability for successive examples of identical models of the same machine due to frame production tolerances. This makes it very difficult to give any general advice when negative matches are found, and each case is pursued individually. There seems room for some improvements in tyre recommendation procedures on both tyre and machine manufacturer fronts, especially for tubeless tyre replacements.

4.2 APPLIED RACING TECHNIQUES.

On several stands at the Show my attention was drawn to a firm which had applied racing car experience to improving the wet weather performance of disc brakes on motorcycles. I obtained contact information for Peter Wardle at Applied Racing Techniques, and subsequently corresponded with him after my return to Australia, as a result of numerous expressions of special concern about this issue as expressed to Authorities in Canada, U.K., U.S.A., and in Australia (e.g. HOR 1978).

Figure 5 shows an ART slotted disc fitted to a Honda CB 400 road machine. This machine had been purchased by a member of ART's staff, and the dramatic drop in braking efficiency experienced in wet weather was the reason for ART diverting attention from their racing car and kart development. ART specialise in Formula 2 racing cars and 100 cc karts, and are

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* Unfortunately no comments were made on the choice of tubeless tyre rim profile (e.g. the MT rim specification now adopted by Honda), although several warnings were given that cast wheels (as distinct from COMSTAR's) seemed to be having sealing problems.

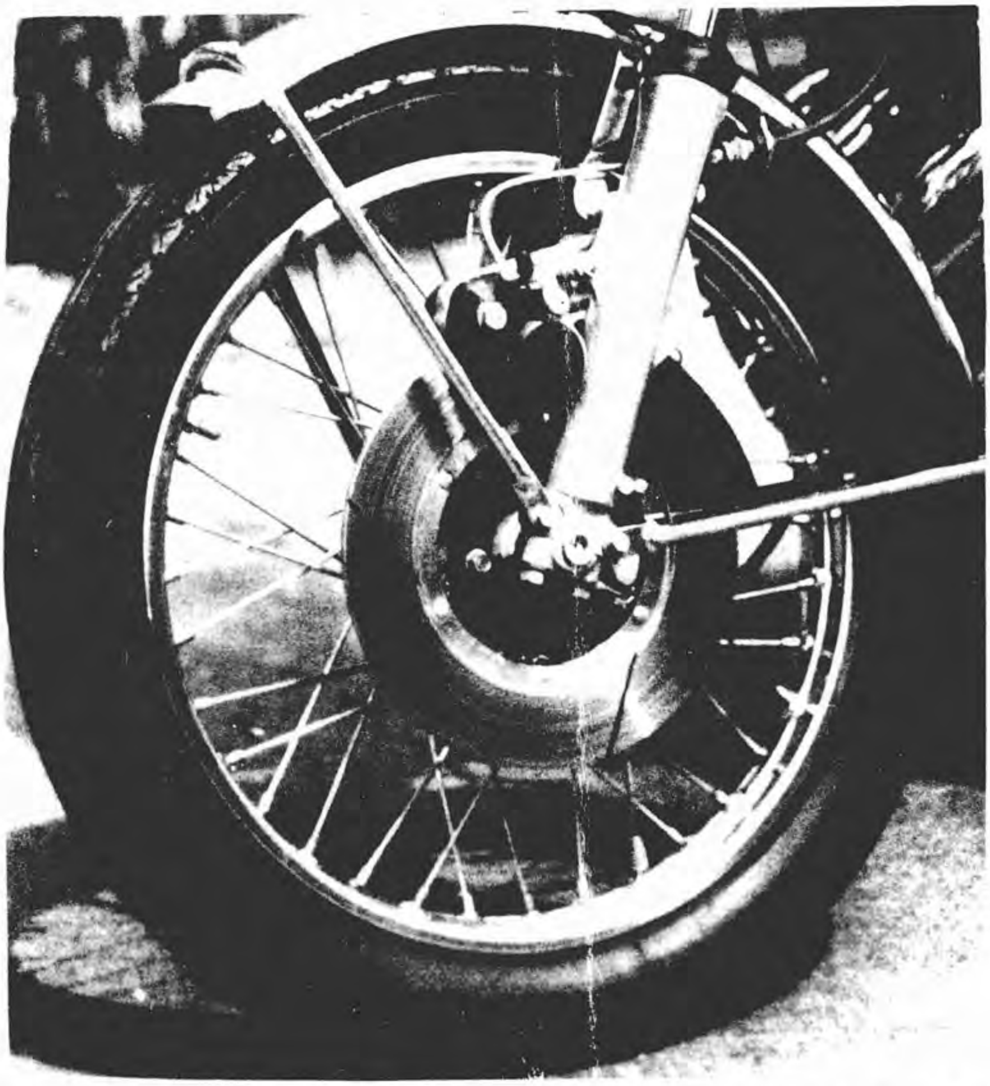

FIGURE 8: ART SLOTTED DISC FITTED TO HONDA CB400 MOTORCYCLE

FIGURE 9: LATER 1978 ART TRIPLE SLOT CONFIGURATION ON A YAMAHA TZ 350E STAINLESS STEEL DISC

the sole concern working with Dunlop on joint tyre and chassis development for karts: a presently unique arrangement for Dunlop. At this time (1977) ART had been experimenting with machining slots into the surface of discs to improve *dry weather control*, and found that the improvement in "feel" and consistency permitted competition drivers to delay braking by as much as 50 yards into corners*.

The motorcycle experiments then undertaken provided an immediate improvement in terms of a reduced time lag for the initial response, and also a shorter stopping distance as showed by the results of some independent tests (Robinson 1978) at different pressures applied in the hydraulic disc brake actuation line. TRRL and Triumph appraised the ART slotting system, and reported favourably.** The conditioning procedures required to ensure that such results are generally applicable and relevant are fairly extensive and Robinson's results should therefore be regarded as indicative only rather than definitive.

The minimum slot configuration for effective performance turns out to be *three* angled to trail in the direction of rotation (Figures 8, 9). Both the width and the angle of the slot have proved to be critical to the water clearance properties, and the successful configuration patterns are subject to U.K. Registered Design 982076. Fig 9 shows the latest pattern on a Yamaka TZ350E.

Similar tests have also been carried out on the effects of different disc brake pad materials and shape modifications under the same experimental conditions. These correspond well with the approximate results previously reported by Honda (Wigan 1977): it should be noted that slotted pads are already being fitted to many Japanese machines on sale in Australia.

The test results shown correspond to stopping from 48 km/h and use the brake line pressures encountered in normal use as measured in the field. It is important to note that the water application was NOT the discredited immersion procedure common to the U.S. FMVSS 122 and the Australian ADR 33, but roughly corresponds to the validated spray-on test procedure developed by HSRI for NHTSA as part of the tow system devised as a practical alternative to the potentially "hazardous"*** and "inadequate"*** procedures specified in FMVSS 122 (Ervin, MacAdam, Watanabe (1977*a*, 1977*b*). Wardle pointed out that the optimum slot configurations for racing differ from those for road use, as racing designs are required to expedite *dust* clearance for swift and consistent brake reaction times under *dry* conditions, while road designs are primarily for water clearance and to work at slower speeds on a cold disc. The author is in favour of the setting up of an experiment in Australia to check on some of these claims and results. This is also a recommendation of the House of Representatives Road Safety Committee (HOR 1978). The use of sintered metal brake pads was recently found to provide a practical solution (Wigan, 1977*b*).

* A similarly successful program to improve dry weather response and controllability was carried out by the Matich Organisation in conjunction with Repco during the period 1970-73 and all the test program results and films are now thought to be held at Patons Brakes. Matich has as yet been unable to retrieve these data for re-examination for motorcycle purposes.

** However see Wigan (1978b) for the subsequent progress up to September 1978.

*** Page 113 of Ervin *et al.* (1977*b*).

4.3 MURRAY EVANS AND ASSOCIATES: INSTITUTE OF MOTORCYCLING

Michael Evans is the Secretary of the Institute of Motorcycling and Director of P.R. Consultants Murray-Evans. The STEP* program has now been endorsed by the U.K. Government and is already in 1,000 shcools within the three years since STEP's initiation as an Industry initiative. This should be compared with the RAC-ACU scheme which covered only 80,000 people in 30 years and only 13,000 of these during 1977. Part of the Institute of Motorcycling set of training programs includes getting at the 90 per cent of people who would never otherwise volunteer. "Two-Wheeler Teach-In" is a four hour package which may be supported by the local dealers to assist in providing direct and immediate training for new purchasers. The IMC national scheme is to supplement the Two-Wheeler Teach-In with eight hour voluntary schemes as a natural follow on - just as the Institute for Advanced Motoring Tests for motorcycles and cars provide a natural follow-on to the Ministry of Transport licencing tests. The main target is to get around 130,000 people through the four hour package each year, thereby producing a 90 per cent coverage of new riders/purchasers in three years. The manufacturers have contributed nearly 1 m. towards the training scheme, and STEP is expanding to handle it.

Murray-Evans currently have some further road safety interests, in the use of dipped headlights at night and night driving aids.

5. UNITED STATES: NATIONAL HIGHWAY TRAFFIC SAFETY AUTHORITY

5.1 DONALD BISCHOFF

Dr. Bischoff is no longer responsible for motorcycle safety, but is currently concerned with energy, air quality, and emissions. His personal background includes being an ex-professional motocross rider. He gave me a bird's-eye view of the NHTSA program and results on motorcycle safety over quite some years.

Braking in wet weather is handled by Paul Yoshida in the NHTSA Office of Defects Investigation, a quite separate organisation to the Office of Standards. Wet braking is still subject to active investigation as a result of numerous Defect Reports. The Transportation Research Centre in Ohio is doing tests for Yoshida but are *not* using the FMVSS 122 test procedures (which are virtually identical with ADR 33 in most respects) due to their inadequacy and irrelevance to the problem,but using a towing test procedure developed under contract by Bob Ervin at the HSRI at the University of Michigan under the DOT-NHTSA Contract "Motorcycle Braking Performance" DOT HS-5--1264 (Ervin *et al.* 1977*a,b,c*). This contract was let as FMVSS 122 is regarded as inherently dangerous to the rider carrying out the test (Ervin, 1978) and had encouraged non-functional and inappropriate redesign of hub brakes due to the FMVSS 122 immersion requirements leading to the rejection of perfectly adequate hub water sealing designed. Some Honda machines have been the subject of wet weather braking and some machine stability Defect Reports from users since 1973. This has led to some improvements in that a 3-4 second

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* Schools Traffic Education Program: a moped oriented road safety and vehicle operator course for schools normally promoted by the Institute of Motorcycling.

delay in the actuation of braking performance on saturated discs has now been reduced to 1½-2 seconds. The standard procedures are very poor and the experimental procedures for execution on the live motorcycle are not well specified. Apparently the Japan Automotive Manufacturers Association never came back in detail on the initial basic first draft of FMVSS 122 and as no comment was received this was a major reason for the flow on of FMVSS 122 in its unrefined form to become the FMVSS Standard: Australia simply copied most of FMVSS 122 through to ADR 33 with no further refinement for practicality (Yeend, McKenzie, Milne 1977).

Dynamic tyre failure can be a worrying problem for users and is the cause of two-thirds of all tyre problems in accident terms: this leads to the question as to why there are no safety rims or bolts or locks on so many motorcycles. Research has been done, test procedures developed for safety rims, and checks on contributions to dynamic instability have been completed within NHTSA. In 1974 Honda showed films highlighting successful safety rims.

Dr. David Weir of Systems Technology Incorporated is an authority on motorcycle handling dynamics and is contract manager for NHTSA's on-going work in this area. Weir is currently the Chairman of the Motorcycle Handling Committee of the SAE and took over from Bischoff. This Committee organised a review of motorcycle dynamics at an SAE meeting in May 1978 (Weir, 1978). Doug Roland of AMF Harley-Davidson Laboratories is an ex-NHTSA staff member with special experience on handling developments. The key measured data on tyres is derived from Calspan's work by W.F. Milligan Jr. under the title "High Camber Tyre Tests" undertaken on Calspan's Tyre Research Facility: this data is built into the Calspan motorcycle model, and has been used by Weir at Systems Technology International (STI) to examine tyre mismatch effects on dynamic stability as a prospect for possible new vehicle Standards, and to analyse the over/under-steer gradients as a function of camber stiffness and tyre type and performance. The NHTSA contracts for motorcycle and moped handling safety are administered by Keith Klaber, Joseph Kanianthra and Francis DiLorenzo, who are all in the R. & D. Department of NHTSA (see Appendix I for new (1978) organisational affiliations).

The Washington 1975 International Motorcycle Safety Symposium (NHTSA 1977*a*) contains concise reports on much of the Japanese work on motorcycle lighting. Further conspicuity work is under way, under the guidance of Herbert Miller of NHTSA. The HSRI also carried out a major contract on motorcycle lighting which is worth further investigation. HSRI also undertook some work on rider eye point patterns for mopeds, for motorcycles under 150 cc, in static tests, and for motorcycles of over 150 cc in dynamic tests and found that the eye point patterns were very different from car users. This has real implications for traffic engineering and vehicle design. HSRI also examined glare effects (Sturgis 1977) including banking and full scale tests on motorcycles. Recommendations on 109 changes were made by HSRI. JAMA has also worked on eye point subjects (Taniguchi 1977) and motorcycle headlights (JAMA 1975*a,b,c*).

Bothwell (ex-MIRA*) now has his own consulting business** and has examined some of the less promising or probable devices such as air bags. This was followed by the development of a test procedure for fuel tank integrity. There are very few motorcycle crashes involving fire, and as yet no FMVSS action has been taken. SAE have also drafted a Standard which

* Motor Industries Research Association, U.K.

** CALIBER Design.

has not yet led to official endorsement as an FMVSS Standard. Some of the experimental results suggested that *fibreglass* tanks can be very poor in performance but that *plastic* ones are good - or can be. Consequently a performance rather than a material Standard seems to be most appropriate, if any Standard is to be produced.

NHTSA and JAMA came to the general conclusions that if you engineered crash bars for one particular impact at one particular speed they can help, otherwise they are of no advantage. The "inverted triangle" shaped crash bar was even found to exacerbate any tendency for the machine to loop and roll over. The 1975 Washington Symposium (NHTSA 1977) reports on these areas, and results may also be found under the headings "Near Term Cycle Impact" NHTSA, JAMA "The ESM Program", "Dynamics and Motorcycle Impact", Bothwell and various analytical feasibility studies and a side impact report (Livers 1976) (Bartol *et al.* 1975) (Uto 1977).

Antilock brakes have been studied for some time, and *reliability* and *potential instability* have been identified as key problem issues. Miennert's (1974) AMF system was the first U.S. Study on a full flow device and was too costly as it was based on aircraft technology. AMF has continued work with Kelsey Hayes Brakes under NHTSA sponsorship, and results are reported in Bartol *et al.* (1975) and Hirsch *et al.* (1973). The current emphasis is a joint exercise by NHTSA and Department of the Army at the Harry Diamond Laboratories. This is not an electronic device but is fluidic controlled. The TRRL system was appraised by HSRI and by STI and HSRI did this as a contract. A report should now be available from NHTSA. The problems with electronic devices are with the interference, with insufficiently sophisticated logic and lack of fail safe nature of the design. The TRRL system requires rotation to provide power consequently on a totally slick surface there is no power and the brakes remain locked. The final problem was that the TRRL system extended stopping on dry surfaces due to compromises on the choice of optimal coefficient of friction. The Harry Diamond Laboratories (one of the originators of the science of fluidics in control applications) integrate the mean angular acceleration (i.e. angular "jerk"). If a zero crossing of jerk is identified the system switches off the breaking force. This is optimal, but is more difficult in electronic terms as it has to carry out double integration when even a single integration leads to a great deal of hash noise in systems other than fluidic (Tenney 1977, Manion and Tenney 1977).

Test procedures have been developed for braking reliability of control cables, but as yet do not form an FMVSS requirement.

Watanabe of the Honda Motor Co. chaired the ESM Sub-Committee in JAMA and spent 1½ years at HSRI. The Japanese have mirrored the whole U.S. ESM program. Honda in particular are most concerned about improvements in understanding machine stability. Keith Klaber has the source code of the Calspan eight degree freedom model of motorcycle/driver dynamics set up for the PDP 11. David Weir has 4, 6 and 8 degree of freedom models, although the 4 and 6 degree of freedom systems seem to be enough for initial studies in most cases.

Computer simulation shows that wheel compliance plays a part in the weave and wobble modes but nothing else has been examined by January 1978: the role of cast wheels had therefore at that stage not been pursued in the stability context.

NHTSA has a rule-making and equipment Standards role but no one person has had specific responsibility for the motorcycle area, and consequently skilled and knowledgeable professionals in NHTSA were in very short supply for quite some time. Very little new work has been undertaken within NHTSA on motorcycle issues in the last two or three years as the programs already initiated run through to completion. Clyde Roquemore set up FMVSS Helmet Standards (FMVSS 218) and was still dealing with issues arising from it when responsibility recently moved to Dr. J.J. Liu*. In 1975 the fields of view of full face and jet style helmets were compared with those of scratch resistant goggles and FMVSS 218 Standards (Gordon and Prince, 1975). An overall bibliography on motorcycles has been produced by NHTSA, and is a good guide to the various NHTSA contract numbers involved (Flynn 1977) although no authors are given and references are all limited to the NHTSA Highway Safety Literature code (HS-....) etc.

5.2 H. MILLER AND L. BUCHANAN

Herbert Miller and Lew Buchanan are responsible for rider programs, helmets and mopeds. Miller was the U.S. representative on OECD Group S13, and therefore contributed to the report of that group (OECD, 1978). In January 1978 they issued a project profile statement on sale usage and accident experience of mopeds. Moped sales were 25,000 in 1975, 100,000 in 1976 and 200,000 in 1977. These figures are derived only from motorcycle industry data as there is as yet no unique official definition of a moped. In FMVSS Standards mopeds are a sub-set of "motor driven cycles" (as are motorcycles). The basic and most general definition being engine power of below 5 hp and speed design capabilities of below 30 mph. Consequently mopeds remain a "motor vehicle" and U.S. States are being encouraged to think this way by NHTSA. Currently the National Committee on Uniform Traffic Laws and Ordinances has been reviewing mopeds and there is a draft report which reviews the requirements for mopeds. Miller is in close contact with Stuart Munro in Canada and was to discuss non-novice training assistance in a Canadian/USA experimental need for training and remedial training for older riders in Ottawa the week after my visit, in conjunction with other U.S. safety workers**. NHTSA is also funding a major study at the University of Southern California under Professor Hurt. This is an in-depth study of over 900 motorcycle accidents. The preliminary results are available, although not yet analysed to a publishable stage. Behaviour patterns, pre-crash, are also being studied and all the entire team is composed of traffic experts who are also motorcyclists. This study will be used to decide what skills etc. should be required of novices. The next is then to be to measure skills and knowledge of the rider. The Motorcycle Safety Foundation (who developed the novice test with data supplied by NHTSA, although industry funded) have a close relationship with NHTSA. They are now field testing in Denver, Colorado and if the results are positive will assess accident reductions such measures could provide. David Weir, at STI, is using a simulation and testing package on mopeds under NHTSA contract.

The South West Research Institute is looking into headforms and helmet Standards for Clyde Rocquemore.

Licencing is of special interest for Buchanan and Miller. A test for initial applicants, with a film to support the introductory training stage and equipment to back this up have all been produced. In 1974 a booklet was produced by MSF and NHTSA and the Licencing Authorities of 50 States. A

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* NHTSA Phone: (202) 426 2264.

** Munro later wrote to me regretting that I was not able to attend to contribute: safety workers in the field of motorcycle training should be aware of the extensive National program Munro administers.

Workshop at MSF was then run with the objective to specify an ideal licencing test for motorcycles: the "Motorcycle Operator Licencing Plan" (MSF 1975*c*) resulted on which a booklet was produced covering:

(a) Novice skill test on a range

(b) Motorcycle operators' manual, protection clothing with a little law

(c) A knowledge test of about 25 items.

All these are pre-learner permit requirements. One possible variation on this pattern is being validated in California.

The social cost of accidents is being examined by Barbara Fagin* at the NHTSA (Fagin 1976).

Recent Californian legislation has brought in a new Design Rule that motorcycles should have their headlamps wired to come on when the ignition was on as a registration requirement. Consequently total compliance applies for all users, and has taken effect very quickly. A research project at HSRI is currently under way on a variety of procedures for raising motorcycle and motorcyclist conspicuity, including measurement of the response of *unalerted* motorists using a 3½ mile urban route in Ann Arbor and running an instrumented motorcycle over the route to get mean gap acceptance behaviour. AMA** sponsored work is in progress aimed at looking at the distances at which motorists could accurately in adequately identify closing speed of motorcycles with headlights on and headlights off. With headlights off the initial results suggested that speed estimation by the motorists was adequate, but with headlights on the subjects under-estimated the speed of the motorcycle substantially.

5.3 DR. ROLF EPPINGER

Dr. Eppinger is concerned with the biomechanics of injury, and has just initiated a major study on the pathology of motorcycle injuries, which has previously been inconsistent. Due to American laws and their relationship to the American Constitution, only 50 per cent of motorcyclists now use helmets. The Los Angeles County Coronor (Noguchi) has cooperated with NHTSA and USC to agree autopsy protocols from the head down to vertebra C7. (See also Appendix 2). The autopsy procedure was virtually complete by the end of 1977, a development accelerated by the presence and activity of the USC in-depth study teams in the Los Angeles County.

The biomechanics of head injury and the correlations between impact and phsiological result is still an uncertain area***, where the accumulation of reliable data is a slow process of considerable difficulty. Much of the present Standards work is based on the Wayne State Curve (Guardjian *et al.* 1966) which is based on fractures versus concussion, however many concussions occur without associated fractures. A number of different lines of investigation are now current.

* NHTSA Phone: Extension 7516.

** American Medical Association

*** e.g. Validation studies for head injury impact model. DOT-HS-031-3-740 September, 1977.

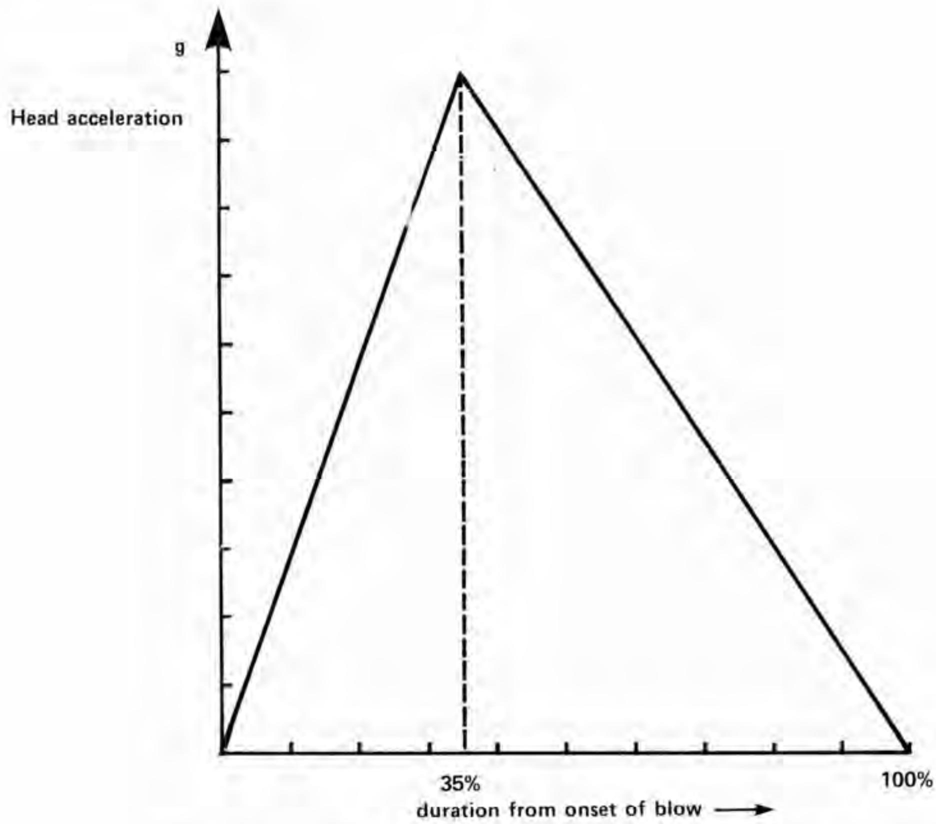

FIG. 10: INDICATION OF POSSIBLY DESIRABLE IMPACT ACCELERATION OVER TIME

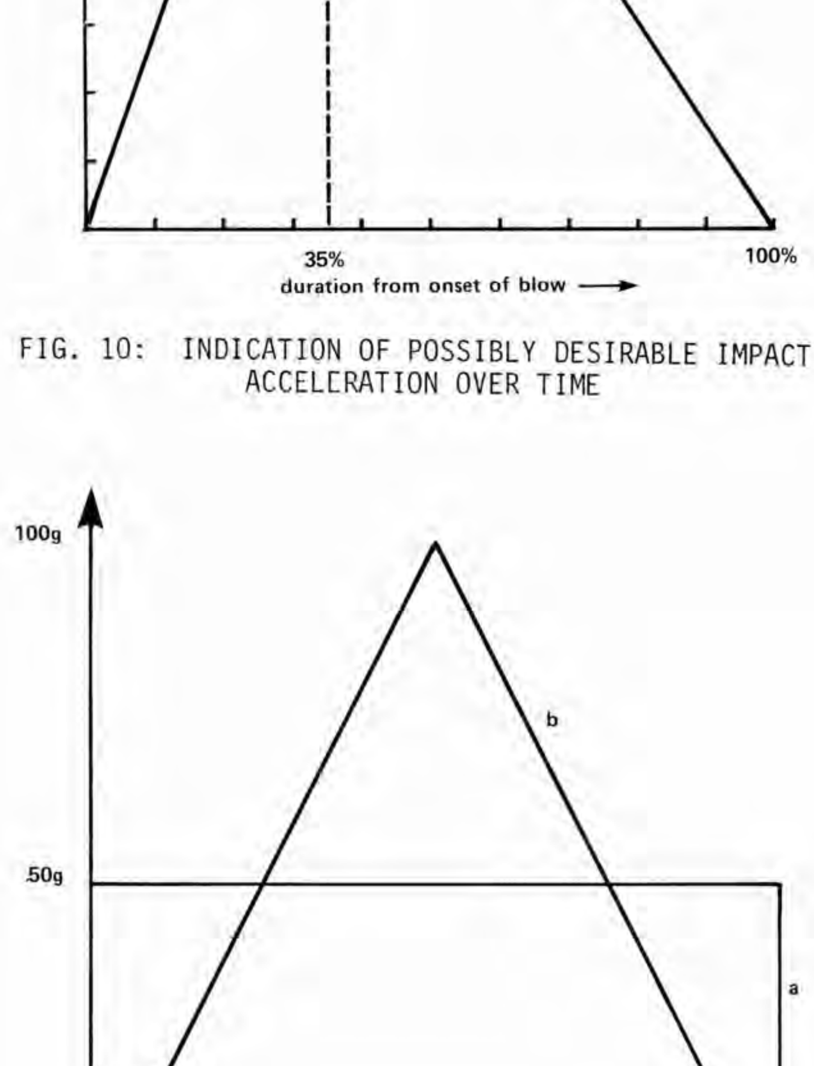

FIG. 11: BLOW ACCOMMODATION CAPABILITIES FOR SPECIFIED LINEAR CRUSH DISTANCE CAN ACCOMMODATE WIDELY DIFFERENT PEAK ACCELERATIONS AS A FUNCTION OF TIME PROFILE.

Rhesus monkeys are being used to measure the effects of different combinations of rotational and translational amplitudes; as it is a slow process, results should not be expected before late 1979. Physical tests are made on the depth of unconsciousness produced and ECG recordings etc. are made to simultaneously measure the electro-physiological factors. Relationships are being sought to link these latter values to the neurological deficit produced by the impact and develop correlations between these and clinical observations.

On a slightly longer timescale (i.e. late 1980 reporting) a direct attack is being made on concussion effects on humans. As boxing is an exercise where humans voluntarily submit themselves to concussion-producing blows, some special equipment has been developed to measure nine different acceleration vectors with FM telemetry in boxing mouthpieces. This will provide a mechanical history to go with the clinical and electro-physiological observations relating concussion with level of loss of consciousness.

The initial stages of this program include some rough and exploratory regressions predicting the *length* of the period of unconsciousness fairly well, and the pathological observations - although very coarse (as AIS level) gave rough and ready agreement. The intriguing point is that the tentative *models* for the two types of measures are rather different. The following discussion is only weakly backed by the thin data to hand, and is simply an emerging set of hypotheses from a few hints coming forward. An impact with a triangular wave form (of acceleration versus time) with a peak 35 per cent along the bottom (time) axis seems to produce the lowest AIS for a specific level of blow (Fig. 10). A possible brain model also tends to favour the same 35 per cent point.

When blows are converted into liner crush distances within a helmet, a linear energy absorption process which gives nice limiting 50g headform deceleration (Fig. 11 line a) may be considerably worse than a 100g peak deceleration with a triangular profile rising to 100g, as the triangular pattern is far more mechanically efficient in terms of using up the available liner thickness before the violent accelerations produced by shell contact are reached. This leads Eppinger to suggest *mechanical reserve* in the liner (at specified impacts) as a possible key factor in helmet design and use. This concept would be of possible value in diluting the simple pass/fail nature of present impact Standards.

Dr. Voight Hodgeson at Wayne State University has developed his own headforms for helmet testing purposes, and there is a ready sale for them to American football helmet manufacturers. These manufacturers have a severity scale of their own and have jointly agreed to set 1500 as a maximum accepted level on this system of testing: Eppinger reports that this step has led to a real reduction in football head injuries as a result.

5.4 J. KANIANTHRA

Dr. Joseph Kanianthra is in what was (until 15 January 1978) the Crash Avoidance Division of the NHTSA. This is now termed the 'Integrated Vehicle' Division and includes motorcycle dynamics work. Complementary Divisions - also in the Office of Passenger Vehicle Research - cover 'Vehicle Engineering' and 'Technical Assistance'. Keith Kleber was also in Crash Avoidance but has now moved*, and taken the NHTSA moped projects and antilock motorcycle braking investigations with him.

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* See Appendix 1.

Kanianthra has current responsibility for Dr. Weir's projects on motorcycle dynamics (Section 10). There is a very active current project on motorcycle handling: six different machines have been thoroughly tested for their capabilities, and a complete test procedure has been developed. The result of this test procedure have also been correlated with subjective measures collected by using rider feedback.

Kanianthra has a special interst in the motorcycle and moped stability field, and has written an in-house motorcycle and rider dynamics simulation model in CSMP. This model is used to evaluate proposed or possible future projects in this area by using the simulation to explore the possible areas of importance. This comparatively simple simulation is not in the public domain, although the complex rider/machine model being developed by Systems Technology (Weir) will be when released (see Section 10.1).

Tyre models were discussed, and Kanianthra agreed that they were crude at present. A current project is under way at the University of Michigan, led by McIver of the Applied Mechanics Department to develop a better car tyre model as part of a *car* and driver simulation model. A bibliography of single track vehicle sources on dynamics, control and tyre effects has recently been produced at ARRB (Wigan 1979*a*).

1978 did not have any fresh motorcycle projects scheduled, as a review of the first wave of work by NHTSA was to be undertaken in the second half of the year. Possible areas of new work include rough road handling controllability parameters by the rider, and accelerated antilock braking developments.

Kanianthra emphasised that his area was that of handling *research* and that Rule Making (FMVSS) was the province of Scott Shadle and D. Perna in this area of NHTSA interest.

6. INSURANCE INSTITUTE FOR HIGHWAY SAFETY*

6.1 L. ROBERTSON

Dr. Leon Robertson is the Principal Analyst for Traffic Safety. The Insurance Institute for Highway Safety is allied to the Insurance Data Institute, and both are directed by W. Haddon. Some of the recent studies on motorcycles include one commissioned by IIHS and carried out by Kraus *et al.* (1975*a*, *b*: Drysdale *et al.* 1974) which investigated medically treated motorcycle injuries in California, and found that 60 per cent of these injuries had not been reported to the police as accidents. This further study was a replication of Foldvary and Lane (1964), but found that motorcycle helmets had reduced fatalities by around 30 per cent. A third study indicated that 40 per cent of motorcycle crashes are left handed across the machine in a country in which driving is on the right. This reaffirms the potential importance of conspicuity. Michigan are even considering trials of a higher power head beam using a strobe flash for even greater intensity than currently available from halogen motorcycle head lamp. This of course pays little attention to opposing driver glare problems and it should be noted that halogen headlamps are *not* currently permitted in cars in the U.S.A.: motorcycles are already an anomaly.

The Kraus *et al.* studies were based on an extensive survey of accidents in Scaramento (Drysdale *et al.* 1974) which found only 39 per cent of the accidents picked up were identified in official police records. The annual incidence of injuries was 1.0/1000 population, with a peak for male

* Watergate 600, Washington DC 20037. U.S.A. Tel (202) 333-0770.

drivers of 18 years. About 4 per cent of all registered motorcycles were involved in an injury producing collision in a single year, and nearly half of the injured motorcyclists suffered serious injury with fractures to most frequent single type of trauma. This was documented in greater detail by Kraus *et al.* (1975*a*), which further emphasises that two-thirds of the injury-involved collisions involved a second vehicle. Detailed analysis of the experience and driver training records of the motorcycle drivers showed that the risk of injury was higher for drivers *with* training than for those without/or those who used their machines frequently irrespective of type of use. This surprising finding is put into a lucid and easily appreciated context by Robertson and Zador (1977) for *all* types of teenage drivers. It is a question of the balance of access to driving at a given age which alters exposure and therefore absolute figures. The Kraus *et al.* (1975*a*) report is interesting in the median accident speed results showed in Table 5. This median speed is 33-64 km/hr (i.e. median value 48 km/hr) compared with 1977 Los Angeles data (see Section 12.2) on 900 motorcycle accidents with a median speed of 51 km/hr (32 mph).

TABLE 5

NUMBER AND PERCENTAGE OF SERIOUS AND NOT SERIOUS INJURIES FOR MALE MOTORCYCLE DRIVERS ACCORDING TO TYPE OF ROAD AND ESTIMATED SPEED AT TIME OF COLLISION, SACRAMENTO COUNTY, CALIFORNIA, 1970.

Estimated speed at time of collision (km/h)	Type of road and severity of injury									
	Highways and county roads					Local city streets				
	Serious		Not serious		Ratio serious/ not serious	Serious		Not serious		Ratio serious/ not serious
	No.	%	No.	%		No.	%	No.	%	
≤32	20	15.7	19	18.3	1.1	11	16.2	22	23.2	0.5
33-64	73	57.5	66	63.5	1.1	47	69.1	71	74.7	0.7
65-113	34	26.8	19	18.3	1.8	10	14.7	2	2.1	5.0
All speeds	127		104		1.2	68		95		0.7

(Source Kraus *et al.* 1975*a*)

The second part of the report of the Kraus *et al.* (1975*b*) work included an analysis of variance of helmet usage in injury accidents which once again convincingly demonstrated that helmets work to reduce the injury level in most accidents where they are in use. The distribution of injury accidents/1000 motorcycles is interesting in that the ratio rises to a maximum at 251-500 cc, and then drops sharply (although with low statistical reliability).

TABLE 6

RATIO OF INJURY PRODUCING COLLISIONS PER 1000 REGISTERED MOTORCYCLES AND OBSERVED AND EXPECTED FREQUENCIES OF INJURY-PRODUCING COLLISIONS FOR MALE DRIVER QUESTIONNAIRE RESPONDENTS ACCORDING TO ENGINE SIZE, SACRAMENTO COUNTY, CALIFORNIA, 1970.

				Questionnaire respondents		
Engine size (in cc's)	No. of registered motorcycles	No. of injury, producing collisions	Ratio of injury producing collisions per 100 motor-cycles	No. of collisions observed	No. of collisions expected*	Ratio observed to expected
<126	11 708	208	17.8	174	265.7	0.7
126-250	4 656	168	36.1	156	179.8	0.9
251-500	3 572	236	66.1	223	128.9	1.7
501-750	1 466	72	49.1	65	51.0	1.3
750+	1 031	38	36.9	36	28.7	1.3
All sizes	27 467[†]	1168[†]	42.5	654	654.1	1.0

(Source Kraus *et al.* 1975*b*).

An important recent IIHS sponsored program has been on the examination of free fall head injuries by HSRI. Two reports cover this work: Snyder *et al.* (1977) and Mohan *et al.* (1978). Children appear on the basis of these studies to be injured *less* severely than adults under similar impact conditions. HSRI have developed a two dimensional simulation of the mechanical movements of bodies under impact conditions which has been validated during this program. Figures 12 and 13 are illuminating when read in conjunction with the accelerations specified in Helmet Standards (usually 300/400g peak accelerations and variously 200 g average over 3ms, 150 g over 6ms, etc.).

Currently Minnesota and California are the only two States with a public school education and training data available: this data is very slim and presently rather unreliable. Robertson stated that insurance data also is a very poor basis for accident analysis in the U.S.A. and that this was his conclusion having analysed car data very carefully (Robertson 1976*b*) and now investigating truck data with the possibility of appraising the motorcycle information at a later stage.

The relationship with the Highway Data Loss Institute is very close: it is a designated Rating Institution, and wrote and maintains a decoding program ("Vindicator") from car identification number to manufacturer. (HDLI 1977). Consequently, by using this program careful analyses can be carried out on car-by-car and model-by-model data bases. This had clear model rating implications for insurance purposes and was therefore hived off to the Highway Data Loss Institute, which now uses this program for model-by-model analyses of cars and vans etc. HSRI use the same data file procedures - though not always the same programs - as part of their own data analyses.

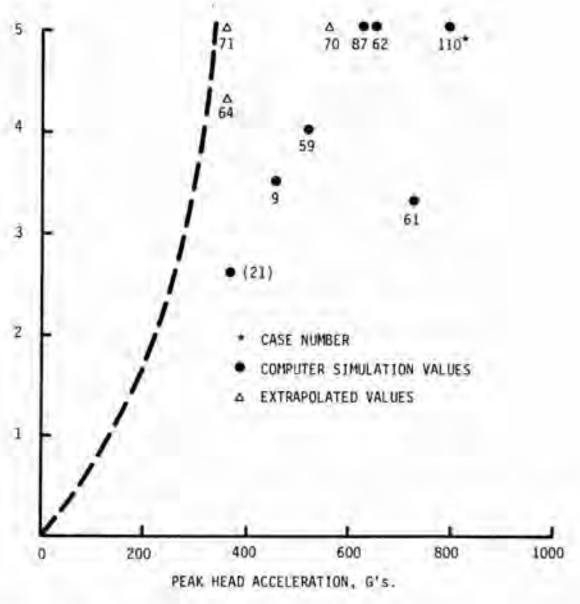

FIG. 12: CHILD HEAD INJURY AS A FUNCTION OF PEAK HEAD ACCELERATION

(Source: Mohan *et al.* 1978)

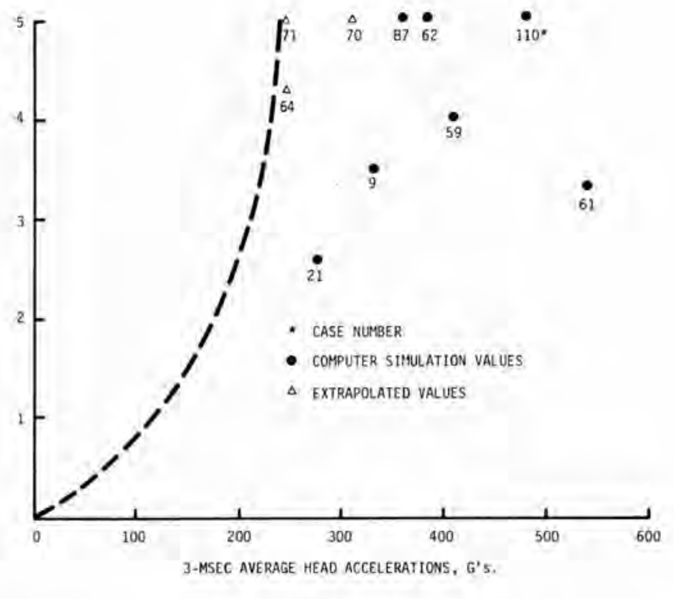

FIG. 13: CHILD HEAD INJURY AS A FUNCTION OF 3-MSEC AVERAGE HEAD ACCELERATION

(Source: Mohan *et al.* 1978).

The Insurance Institute for Highway Safety has been heavily involved in crash and damage testing and fire testing. For example, front and rear crashes at 40 mph produced two severe fires out of six crashes, and at least partly in consequence a new NHTSA test is required to be carried out for car fuel tank protection. Currently truck crashes are being considered or carried out with a view to improved under-run protection.

Robertson expressed very strong interest in the microfiche archive retrieval system (Wigan 1978*c*) now implemented at ARRB and a fairly full set of ARRB accident reports was left with him in fiche format. The fortnightly Insurance Institute for Highway Safety Newsletter will now be sent to us regularly.

7. MOTORCYCLE INDUSTRY COUNCIL*

7.1 MELVIN STAHL (VICE PRESIDENT FOR GOVERNMENT RELATIONS)

The Motorcycle Industry Council (MIC) is an industry representation organisation, which firmly recognises the need to assemble material data as a basis for legislative interaction. An associated organisation (the Motorised Bicycle Institute) carries out a similar task pressing the case for mopeds and motorised bicycles throughout the United States. The data collated by the MIC is interesting and indicative though not always statistically reliable as this is not always required until an issue has been demonstrated to exist. Motorcycle users have been surveyed by Gallop Poll by both the Motorcycle Industry Council and the Japan Automotive Manufacturers Association (JAMA, 1974). They have identified the same key characteristics as might be reasonably expected to be picked out in Australia were similar studies to be carried out here.

The motorcycle market in America is now ageing. The average age of those surveyed in 1970 was 23, in 1977 the average age was 26. The West-Coast Office of the Motorcycle Industry Council specialises in statistics. This is located at Newport Beach, Los Angeles. The Director is Alan Isey. The Statistician is Pamela Amette who has undertaken a Scrapping and Life STudy for the Environmental Protection Authority's

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OCCUPATION	% OF 1975 TOTAL OWNERS
Student	22.5%
Professional/Technical	20.2
Laborer/Semi-skilled	16.8
Mechanic/Craftsman	11.8
Manager/Proprietor	6.6
Farmer/Farm Laborer	6.1
Clerical/Sales	3.6
Other	10.6

TABLE 6: 1975 OCCUPATIONAL DISTRIBUTION OF U.S. MOTORCYCLE OWNERS.

NUMBER OF MOTORCYCLES CURRENTLY OWNED	% OF TOTAL OWNERS
Own 1 motorcycle	68.2%
Own 2 motorcycles	21.9
Own 3 motorcycles	6.8
Own 4 or more motorcycles	3.1
TOTAL	100.0%

TABLE 7: 1975 U.S. DISTRIBUTION OF MULITPLE OWNERSHIP OF MOTORCYCLES

PREVIOUS MOTORCYCLE OWNERSHIP	% OF TOTAL OWNERS
Owned a motorcycle other than the one(s) now owned	55.1%
No previous motorcycle ownership	41.8
Not stated	3.1

TABLE 8: U.S. MOTORCYCLE OWNERSHIP HISTORY IN 1975.

U.S. MOTORCYCLE OWNERSHIP CHARACTERISTICS

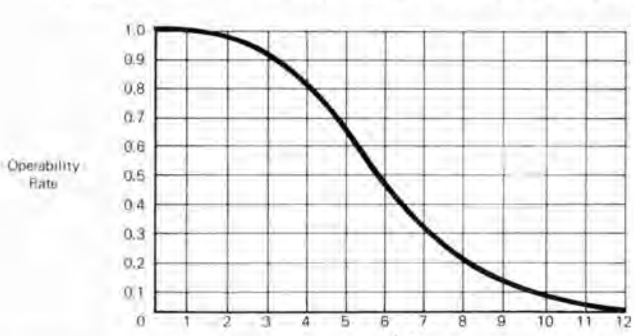
(Source: Motorcycle Industry Council 1977)

	Number of Motorcycles	% of Total Used on Street
Total Motorcycles Registered for Street Use	5,100,000	100%
Motorcycles Used for Commuting	2,960,500	58%
Commuting to Work (at some time)	2,668,500	52%
When used regularly during good weather		
Median # of round trips per week 2.5		
Median # of miles one way 6.0		
Median # minutes one way 14.0		
Commuting to School (at some time)	794,400	16%
Motorcycles Used on Street for Purposes Other Than Commuting	5,025,000	98%
When used regularly during good weather:		
One or more trips taken per week under 2 miles one way	3,117,000	61%
Median # of round trips per week 5.0		
One or more trips taken per week 2.10 miles one way	2,862,000	56%
Median # of round trips per week 3.6		
One or more trips taken per week over 10 miles one way	1,942,000	38%
Median # of round trips per week 2.0		

TABLE 9 : U.S. MOTORCYCLE USAGE 1976

AVERAGE ANNUAL MILEAGE	Total Motorcycles	On Road Motorcycles	Off Road Motorcycles	On/Off Road Motorcycles
1976 Momentary Miles Per Year	1,525	2,215	1,100	965
1976 Accumulated Miles Per Year	2,215	3,100	1,500	1,600

TABLE 10 : 1976 AVERAGE ANNUAL MILEAGE



Age	Operability Rate
0.5	1.00
1.5	0.98
2.5	0.96
3.5	0.90
4.5	0.75
5.5	0.55
6.5	0.37
7.5	0.26
8.5	0.17
9.5	0.10
10.5	0.05
11.5	0.02
12.5	0.01

FIGURE 14 : MOTORCYCLE OPERABILITY RATE

U.S. MOTORCYCLE USAGE PROFILE FOR 1976.
(Source: Motorcycle Industry Council, 1977)

requirement for "useful life" definitions. She also authored the Motorcycle Statistical Annual (MIC 1977) and a new version was due for April, 1978. A number of documents have been produced which shed light on the characteristics of the American motorcycle market. In 1975 Cycle Magazine carried out a review "Motorcycle After Market Study, April 1975" of their readership (which nears half a million). The data was aimed mainly at accessory and manufacturer coverage and is not terribly helpful for planning purposes although providing an indicative view of the importance of after market products. A motorcycle ownership profile study was carried out by Newsweek in January 1975 (Survey Research Corporation, 1975).

Of the American users surveyed, 85% stated that motorcycles were a good transport/fuel economy substitute for a car, and 63% would consider purchase of a motorcycle rather than a further car. This is a surprisingly high level, as 23% of respondents used their motorcycles solely *off* road, and only 52% used theirs solely *on* the road. As multiple motorcycle ownership is common, the 1975 figures of 30% owning motorcycles of under 100 cc and 29% those over 750 cc are not a clear indication of exposure to risk by size of machine. The maturing state of the U.S. market is illustrated by the fact that 20% of riders had over ten years experience in 1975, 30% over seven, and 43% over five, only 13% had less than a year: also, only one-third of respondents had not previously owned a motorcycle by 1975. Exposure figures are also affected by the fact that only half of respondents actually *ride* their machines as a means of transporting the motorcycle: the other half uses trailers, pickup, vans, etc. to get their machines to a place where they will use them.

Tables 6 to 10 are drawn from The 1977 Statistical Annual, and give a succinct picture of the U.S. user profile in 1975-76. Quoting from this Annual:

> "Motorcycle owners were most frequently reported to be students (22.5%) with regard to their current occupation, 20.2% held professional or technical positions; 16.8% were labourers or semi-skilled labourers, and 11.8% were mechanics or craftsmen. An additional 12.7% were split between those owners who were managers or proprietors and those involved in farming. Only 3.6% held clerical or general sales jobs.
>
> The median household annual income was $14,260. Half (49.1%) of the motorcycle owners reported their total household annual income to be from $10,000 to $19,000. The remainder of owners reporting household income was evenly divided between those earning less than $10,000 per year and those earning $20,000 per year or more."

Figure 14 should be compared with the Australian Motorcycle survival curves given and discussed in Wigan and Thoresen (1979), where the average life expectancy of Australian motorcycles was shown to be 6 years on 1971 data and with the Japanese data in Figure 15. The 50% operability rate shown in Figure 15 is also at 6 years, and is roughly comparable.

Electrical cycles are apparently now available on a very limited scale in America and a short list was given*. None of these are yet sufficiently widely available to be as yet of any great significance.

---

* 1. Auranthetic Corporation, Burbank, California
2. Solo Klein a Moto, CMBH, West Germany (currently on sale but mainly for industrial internal movements).
3. Corbin Gentry, a lightweight vehicle currently in production mainly for a golf buggy type of usage.
4. La Vateur Electric, Paris 16, France.
5. Societe Bertin et Cie, 78 Plaisier, France.
6. Battery Powerant Corporation, Golden, California.

The JAMA survey of Japanese motorcycles and users was published at the end of 1974*, and gives a clear picture of motorcycle usage in Japan. The larger the machine the further it travels each month, and the *older* the machine the *smaller* the distance covered each year. Machines below 125 cc are mainly used for commuting or work purposes, and those above mainly for leisure purposes. Under 50 cc machines are 91% used for work, 50 to 125 cc are 90%, but 125-200 cc only 40% with larger machines of over 250 down to 10% of usage for work.

The average speed of motorcycles in use is shown in Table II.

Size (cc)	City (km/hr.)	Suburban	Highways	Expressways
50	36	44	-	-
125	40	49	-	-
250	48	60	79	92
251 +	52	65	82	95

TABLE II AVERAGE TRAVEL SPEEDS BY MOTORCYCLES IN JAPAN

(Source: JAMA 1974)

The average length of round trips is given, and is collated in Table 12.

Size (cc)	COMMUTING (WORK AND SCHOOL)		LEISURE KM		ERRANDS KM		WORK KM	
	km	: (minutes)	km	: (minutes)	km	: (minutes)	km	: (minutes)
50	1.3	(4.1)	3.9	(7.3)	1.4	(3.5)	4.7	(15.1)
125	1.8	(3.9)	6.0	(11.1)	1.6	(4.0)	4.8	(15.6)
250	3.3	(7.5)	29.9	(49.3)	3.1	(8.0)	4.8	(12.6)
251+	4.5	(9.5)	54.7	(90.3)	3.1	(7.1)	3.9	(9.6)
OVERALL	1.8	(4.1)	9.4	(16.4)	1.7	(4.2)	4.7	(14.8)

TABLE 12: AVERAGE LENGTH AND DURATION OF MOTORCYCLE JOURNEYS IN JAPAN

(Source: JAMA 1974)

The fuel consumption and working life of motorcycles are both reviewed in detail by JAMA (1974), and the survival curves shown in Figure 9 bear a fairly close resemblance to Australian data of a similar vintage (1971) with the Japanese data displaying an average life of 5½-6 years (if 6 years for Australia, (Thoresen and Wigan 1979)), and a slightly slower initial drop off with more pronounced drop after 6 years.

*It should be noted that at that date few mopeds were in use, and the under-50 cc category was almost entirely of small motorcycles of conventional type.

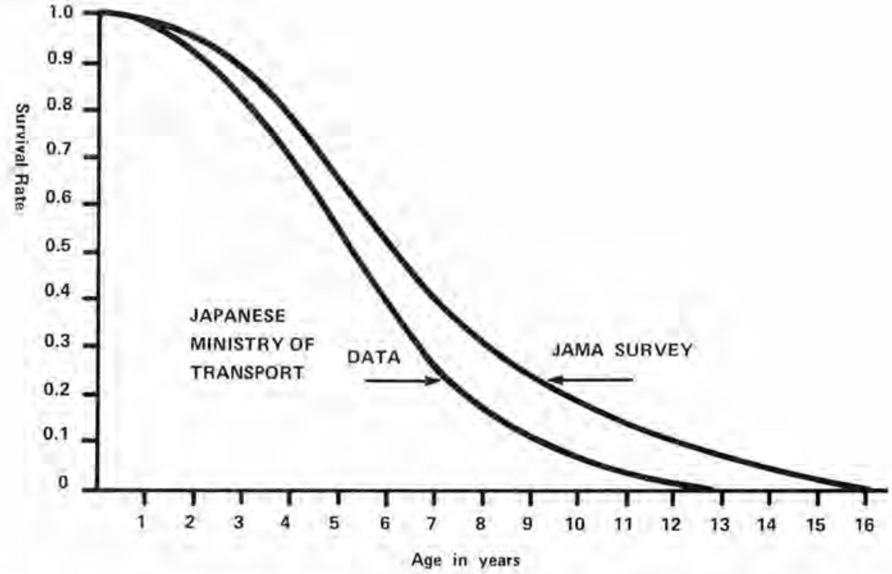


FIG. 15: SURVIVAL CURVES FOR JAPANESE MOTORCYCLES OF THE EARLY 1970's.

(Source: JAMA 1974).

The American Environmental Protection Authority has required the first stage of restriction on pollution emissions from January 1st, 1978 for street bikes. The first stage has proved to be reasonably acceptable and possible to achieve while the 1981 Standards currently planned are so severe that the lead time may well be inadequate to modify or adapt the larger two stroke motors for production within the presently stipulated period. It should be noted that on the EPA's own figures that less than 1 per cent of all motor-sourced air pollution comes from motorcycles not yet subject to pollution control. This may be compared with similar observations made by the Japanese, with very different Government policies resulting (Wigan, 1977). One of the effects of such EPA legislation is to have very severe effects leading to the rapid freezing out of small manufacturers due to the enormous investment required to revise the present technology to meet the Standards specified. The noise standards from the environmental protection agency were still due in their final form for the end of February, 1978 at last estimate (Jan. 1978). They are due in the form of a "Notice of proposed rule-making" which can be expected to take effect on the 1980-81 model year.

The U.S. Department of Transport NHTSA is due shortly to put out a shopping list of possible proposed standard areas (The "Docket"). This has not as yet been published but was due some time 1978.

The associated Motorised Bicycle Association has been pressing with considerable success for mopeds, several of which are now manufactured in the U.S.A. Table 12 is a consolidated list of legislation affecting these vehicles, and is updated and reissued regularly by the Motorised Bicycle Association. Appendix 3 is a collation of the various definitions used for mopeds in the U.S.A., which may be compared with others in Tables I and 2.

Prepared by.
Motorised Bicycle Association
1001 Connecticut Ave. N.W.
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August 22, 1977

CURRENT MOTORISED BICYCLE LEGISLATION

	CC	POWER	MAX.SPEED	REGN.	DEFINED	MIN. AGE	LICENCE	INS.	HELMET	
Virginia	none	less than 1 bhp	20	no	bicycle	16	no	no	no	
North Carolina	none	less than 1 bhp	20	no	bicycle	16	no	no	no	
South Carolina	none	less than 1 bhp	20	no	bicycle	12	no	no	no	
Texas	less than 60	none	20	yes	motor assisted bicycle	15	yes (written test only)	no	no	(1) Ohio amended off. 4/1/78: min. age 14, any valid driver's lic or motorised bicycle lic.
Ohio(1)	none	less than	20	no	bicycle	none	no	no	no	
Michigan	no more than 50	max. 1.5 bhp	25	yes $2 yr.	moped	15	any valid or moped licence (no road test).	no	no	
Nevada	none	none	30	no	moped	16	any valid	no (fin. resp)	no	
California	none	less than 2 gross bhp	30	no	mot. bicycle	15	any valid or learner permit	no (fin. resp)	no	
Hawaii	none	1.5 bhp or less	none stated	no	bicycle	15	no	no	no	
New Jersey	less than 50	no more than 1.5 bhp	25	no	bicycle	15	no	no	no	
Kansas	no more than 50	no more than 1.5 bhp	25	yes $5 yr.	mot. bicycle	14	any valid or licence w/writ. test only at 14	no (fin. resp)	no	
New Hampshire	no more than 50	no more than 2 bhp	30	yes $3 yr.	moped	16	any valid	no	no	
Rhode Island	none	no more than	25	yes $10 yr.	mot. bicycle	16	any valid	no	no	
Indiana	no more than 50	no more than 1.5 bhp	25	no	mot. bicycle	15	no	no	no	Amended off. approx. 8/31/77
Maryland	less than 50	less than 1 bhp	none stated	no	bicycle	16	any valid	no	no	
Connecticut	less than 50	no more than 2 bhp	30	no	bicycle	16	any valid	no	no	
Arizona	50 or less	1.5 bhp or less	25	yes $8 yr.	ped. bicycle w/helper mot.	16	any valid	no (fin. resp)	no	
Iowa	no more	none	25	yes $5 yr.	motorised bic. or motor bic.	14	any valid or mot. bic. lic. at 14, no road test	no (fin. resp)	no	
Florida	none	max. of 1.5 bhp	25	no	moped, under bicycle def.	15	no	no	no	
Pennsylvania	no more than 50	no more than 1.5 bhp	25	yes $6 yr.	motorized pedalcycle	16	any valid	yes (not no fault)	no	
Louisiana	no more than 50	no more than 1.5 bhp	25	no	mot. bicycle	15	any valid	no	no	
Massachusetts	no more than 50	no more than 1.5 bhp	25	yes $3.-2 yrs.	mot. bicycle	16	any valid or learner permit	no	no	
New York a)	none	none	20	yes $5 yr.	Ltd. use Class C motorcycle.	16	any valid or special lic.	no (fin. resp)	no	
b)	none	none	21-30	yes $5 yr.	Ltd. use Class B motorcycle	16	any valid or special lic.	yes	yes	
New Mexico	less than 50	none	25	no	mot. bicycle	none stated	any valid or restricted	no	no	
Vermont	50	max. 2 bhp	30	yes $10 yr.	Mo-ped	16	any valid	no (fin. resp)	no	
Arkansas	no more than 50	no more than 2 bhp	30	no	mot. bicycle	14	any valid or spec. licence at 14 yrs.	no	no	
Wash. D.C.	no more than 50	no more than 1.5 bhp	25	yes $3 yr.	mot. bicycle	16	any valid or mot.bic.permit no road test	no (fin. resp)	no	
Delaware	less than 50	no more than 1.5 bhp	25	yes $5.-3 yrs.	moped	16	any valid	no	no	
Minnesota	less than	max. 2 bhp	30	yes $3 yr.	mot. bicycle	16	any valid or mot.bic.permit	no (fin. resp)	no	
Tennessee	no more than 50	no more than 1.5 bhp	25		mot. bicycle	16	any valid	no	no	
Colorado	no more than 50	no more than 2 bhp.	30	yes $5.-3 yrs.	mot. bicycle	16	any valid	no	no	
Maine	no more than 50	no more than 3 bhp	30	yes $5 yr.	moped	16	any valid	no (fin. resp)	no	

TABLE 12: CURRENT MOTORISED BICYCLE LEGISLATION : AUG. 1977.

8. MOTORCYCLE SAFETY FOUNDATION

8.1 ADAM JOHNSON: DIRECTOR OF LICENCING AND LAW ENFORCEMENT

I made an appointment to see the Motorcycle Safety Foundation facilities and staff after discussing training and task analysis (Motorcycle Safety Foundation 1974) with NHTSA. Unfortunately the weather forbade this by presenting a major snowstorm. Adam Johnson and I then arranged to meet between TRB sessions. The Motorcycle Safety Foundation was founded by the six major manufacturers with support based on their declared market shares in the U.S. market in 1973: Honda, Kawasaki, Suzuki, Yamaha, AMF-Harley Davidson, and Norton Villiers Triumph. The present market shares (1977/8) were known in June 1978 as 40% Honda, 14% Suzuki, 18% Kawasaki, 22% Yamaha, 6% AMF with NVT defunct. MSF was part of the Motorcycle Industry Council up to 1974, when it became a separate entity with a Board of AMF, Honda, Suzuki, Kawasaki and Yamaha. The level of funding is about $US1 m. p.a. including capital expenditures. There are now 23 staff including 10 professionals and a 2 acre education and training area adjoining the Linthicum (Md.) Offices.

The development of the training fell into two distinct phases: first, the 'Beginning Riders Course' was developed by pulling in data from all possible sources, and assembling a Stage 1 novice course. This is specified briefly in MSF (undated *a*, *b*). Second, two years of research was carried out, including detailed task analyses of the rider requirements (Motorcycle Safety Foundation 1974*a*) by the National Public Science Research Institute at Alexandria (Va), and detailed photographic analyses of motorcycle and rider behaviour. (McPherson and McKnight 1976).

This work led to the Stage 2 course for novice riders which has been used since 1976. It is a 23 hour procedure, with 3 hours of street riding, 11 hours of on-cycle training, 10 hours of classroom work, and 2 hours of testing. This is a comprehensively documented course, with a guide book (MSF 1976*a*), a range design guide (MSF 1977), a Motorcycle Operator Skill Test (MSF 1976*b*), and an Administrators Manual (MSF 1976*c*). The latter two documents being produced with the NPSRI under the U.S. DOT Contract DOT-HS-01143. The comprehensive task analysis report produced by NPSRI for MSF (MSF 1974) has been used extensively in developing training material and courses. Table 13 is an extract from this massive volume which illustrates the coherence and coverage of this document. The "criticality" columns BF, EP, AL, AS, C require explanation: quoting from MSF 1974*a* -

"Criticality Factors

The four criticality factors are defined as follows:

Behaviour Frequency (BF) - the frequency with which motorcycle operators are called upon to exhibit the behaviour.

Error Probability (EP) - the likelihood that a behaviour would be performed incorrectly when it is required.

Accident Likelihood (AL) - the likelihood that an accident will occur if the behaviour is incorrectly performed.

Accident Severity (AS) - the extent of loss (that is, degree of property damage, extent of injury, etc.) likely to be sustained in an accident resulting from failure to perform the behaviour correctly.

$$\text{Criticality} = \frac{\text{Behaviour}}{\text{Frequency}} \times \frac{\text{Error}}{\text{Probability}} \times \frac{\text{Accident}}{\text{Likelihood}} \times \frac{\text{Accident}}{\text{Severity}}$$

CODE	KNOWLEDGE AND SKILLS
83-11	Cargo should be placed low enough on the motorcycle to avoid raising the motorcycle's center of gravity to the point where it interferes with the operator's ability to maintain balance. Cargo should not, on the other hand, be placed so low that it drags on the surface during turns.
83-12	In general, any load should be placed as far forward as possible, without crowding the operator or interferring with the operator's use of the footbrake or gearshift.
83-13	Weight placed behind the rear axle tends to lighten the front end, adversely affecting the motorcyclc's handling characteristics in turning and braking maneuvers. At higher speeds, it can result in front wheel "wobble".
8-15	Cargo mounted on the front of the motorcycle can interfere with the operator's vision and steering.
8-16	Cargo which is placed near the drive chain or wheels could become lodged in the wheel or between the chain and sprocket. Both possibilities can result in a locked rear wheel.
8-17	Uneven distribution of cargo, e.g., greater weight in the right saddlebag than in the left saddlebag, can result in a tendency of the motorcycle to lean, and therefore to pull to one side.

CODE		BEHAVIOURS	BF	EP	AL	AS	C
83-1		PLACES CARGO IN PROPER POSITION					
83-11	*	Places load as low as possible on motorcycle	3	3	1	1	1
83-12	*	Places load as far forward as possible	3	3	1	1	1
83-13	*	Avoids placing heavy loads behind rear axle	2	3	2	2	1
83-14	*	If possible, loads cargo in such a way as to prevent obstruction to mounting and dismounting	3	2	1	1	1
83-15	*	Avoids loading cargo on front of motorcycle	3	1	1	1	1
83-16	*	Keeps load away from wheels and rear drive chain	3	1	1	1	1
83-17	*	Distributes weight evenly to either side of motorcycle	3	2	1	2	1

83 - LOADING CARGO

TABLE 13: Extract from the NPSRI "Motorcycle Task Analysis" (Motorcycle Safety Foundation 1974).

The first three factors - behaviour Frequency, Error Probability, and Accident Likelihood - determine the frequency of accidents involving a particular behaviour. The fourth factor represents severity. All four factors together provide an index of the criticality of a particular behaviour to safety. Being a function of accident frequency and severity, overall "criticality" represents an estimate of "loss" attributable to a particular motorcycle operating behaviour.

The overall criticality indices follow a "reverse J-shaped" distribution similar to that generally observed for accidents or accident losses. Most of the behaviours fall in the "1" category meaning that they are not highly associated with accident loss. The number of behaviours at each of the high levels of criticalities falls off consistently with very few behaviours at the "9" level."

This material was drawn upon heavily for the improved Motorcycle Operator Manual (California DMV 1975) being used in the California Licencing experiment discussed in later sections.

The Motorcycle Rider Course is sold for several hundred dollars as a complete package of materials including films, film strips, classroom material, on-range prompt cards, and Instructors Guide. Courses have been run on compacted, unsealed, surfaces with considerable success, and NHTSA considered a one-third million $US demonstration project on this package, but a recent case in North Carolina has recognised driving as a limited *right*. Consequently the complications ensuing for any fresh large scale licencing experiments need to be reassessed. The MSF has published the proceedings of a Workshop on Licencing (MSF 1975*c*).

Eight Universities have had *instructor* training assistance*, and there are now 60 trained instructors in Universities carrying out the training of secondary school teachers and police as instructors in their turn. This is a 50hr/3 credit course in these universities (MSF 1975*a*, *b*).

A total of 3800 MSF certified instructors have now been trained, and in addition special block courses for the Military may be added to this number. As yet insufficient time has passed or data been collected for a proper evaluation to have been completed. However, Jefferson County (Colorado) is currently the subject of an administrative feasibility assessment for an appraisal, and Federal funds are scheduled for a project in the 1979 (fiscal year).

Four States** now *require* motorcycle driver education as a prerequisite to obtaining a licence before the age of 18, and there are numerous State Bills in progress to introduce voluntary schemes for child and adult training, with Federal funding support. The MSF regularly updates a comprehensive summary of motorcycle legislation for all US States, and the December 1977 issue is reproduced in full as Figure 16. The community education courses run by MSF draw on a wide cross section of the population. 60% are adults with a median age of 26, and over 40% are female. This is of course a cause for safety concern due to the severe under-representation of young male beginner bike riders in this profile.

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* including Michigan State, Texas A & M, San Diego State, NYU (Albany), CMSU (Miss), SIU (Illinois).

** Minnesota, Maine, S. Dakota, N. Mexico

MOTORCYCLE SAFETY FOUNDATION

CYCLE SAFETY INFO

6755 ELKRIDGE LANDING ROAD
LINTHICUM, MARYLAND 21090
(301) 768-3060

STATE MOTORCYCLE OPERATOR LICENSING PROCEDURES

1978

STATE	SPECIAL LICENSE OR ENDORSEMENT	LEARNER'S PERMIT	DURATION OF LICENSE	MINIMUM AGE WITH DRIVER EDUCATION	MINIMUM AGE WITHOUT DRIVER EDUCATION	MOTORCYCLE SAFETY EDUCATION A PREREQUISITE TO LICENSING	MOTORCYCLE KNOWLEDGE TEST	OFF-ROAD SKILL TEST	IN-TRAFFIC SKILL TEST	CYCLE INSPECTED	RIDER GEAR INSPECTED	REEXAMINATION REQUIRED	Reexamined for: Vision	Knowledge	Off-Street	In-Traffic
Alabama					14/16[30]											
Alaska	●	● [3]	3		14/16[30]		●	●		●	●	3	●			
Arizona	●		3		16		●	●		●	●	3	●	●		
Arkansas	●	● [4]	2	14[12]	16		● [13]	● [13]		●	●					
California	●	● [10]	4	16	18		●	●	● [16]			4	●	●		
Colorado	●	● [7]	3	15½	16[14]		●	● [15]		●	● [24]	3	●			
Connecticut	●	◉ [4]	2/4	16	18		●	●	●	●	● [24]					
Delaware	●	◉ [4]	4	16	18		●	●		●	●	4	●			
D.C.	●	◉ [4]	4		16		●		●	●	●	4	●			
Florida					15[16]											
Georgia	●	● [6]	4	16	16		●	● [15]	●	●	●	4	●			
Hawaii	●	◉ [5]	2/4		15		●	●	●	●	● [21]	2/4	●	●		
Idaho				14	16											
Illinois	● [36]	● [10]	3	16[35]	18		●	● [15]	●	●	● [24]	8	●			
Indiana				16 yr 1 mo	16 yr 6 mo				● [18]	●		4	●			
Iowa	●		2/4	16	18		●	●	●	●		2/4	●			
Kansas	●	● [4]	4		14[37]		●	●		●	●	4	●	●		
Kentucky	●	◉ [4]	2	16	16		●		● [18]	●	●					
Louisiana	●	● [11]	2	15	15		●	● [19]	●	●	●	4	●	●		
Maine	●	◉ [8]	2	16	17	● [32]	●		●	●						
Maryland	●	◉ [5]	4	16	18		●	● [15]		●	●					
Massachusetts	●	◉ [8]	4	16½	17		●	●	●	●	●	4	●			
Michigan	●	● [7]	4	16	18		●	● [15]		●	●					
Minnesota	●	● [3]	4	16	18	● [22]	●		●	●	●	4	●			
Mississippi				15	15		●	● [19]								
Missouri	●	● [4]	3		16			●		●	●	3	●			
Montana	●	● [5]	4	15	16		●	●	●	●	● [20]	4	●			
Nebraska	●	● [10]	4		16		●		●			4	●	●		●
Nevada	●	● [9]	4		16		●	●		●	●					
New Hampshire	●	◉ [2]	4	16	18	● [29]		●		●	●	4	●			
New Jersey	●	◉ [4]	2	17	17		●	●	● [11]	●	●	10	●			
New Mexico	●	● [4]	1/3	15	16	● [24]	●		● [26]	●	●	2	●			
New York	●	◉ [10]	4		16[28]		●		●	●	●	4	●			
North Carolina	● [17]		2/4	16	18		●	●		●	●	2/4	●			
North Dakota	●	◉ [8]	4	14	16	● [27]	●	●		●	●					
Ohio	●	◉ [8]	4	16	18		●	●		●	●					
Oklahoma					14		● [25]		● [25]	● [25]	● [25]					
Oregon	●		4		16		●	●	●	●	● [20]					
Pennsylvania	●	◉ [9]	2		16			●		●	●					
Rhode Island	●	◉ [5]	2	16	18			●		●	●					
South Carolina	●	● [8]	4	15	15		●	●		●	●	4	●			
South Dakota	●		4		14		●	●	●	●	●	4	●			
Tennessee	●		2		16[36]		●	●	●	●	●					
Texas	●	● [10]	4	16	18[33]		●	●	●	●	● [21]	4	●			
Utah	●	◉ [4]	4	16[31]			●	●			●					
Vermont	●		2	16	18		●	●		●	●					
Virginia	●	● [8]	4	16	18		●	●	●	●	●	4	●			
Washington	●	● [8]	2	16	18		●	●		●	●		●			
West Virginia				16	16			● [18]		●						
Wisconsin	●	◉ [6]	2	16	18		●	●		●	●	4	●			
Wyoming	●	● [10]	3		16		●	●		●	●	3	●	●		

◉ Mandatory Learner's Permit Required

1 Maximum 10 days
2 Maximum 30 days
3 Maximum 45 days
4 Maximum 60 days
5 Maximum 90 days
6 Maximum 120 days
7 Maximum 150 days
8 Maximum 6 months
9 Maximum 8 months
10 Maximum 1 year
11 Maximum 2 years
12 Age 14-16, restricted to 250cc or less with parental consent.
13 Age 19 and above, no test with declaration of 1 year of riding experience.
14 Learner's permit issued at age 15½ if enrolled in approved course.
15 Off-street except when facility not available.
16 Age 15, restricted to cycle of 5 brake horsepower-knowledge test only.
17 Required for operating 190cc or larger.
18 "Motorcycle only" license applicants.
19 Provided only at select sites.
20 Only helmet inspected.
21 Helmet inspected for applicants under age 18.
22 Under age 18.
23 14 locations use in-traffic and minimal off-street test.
24 Motorcycle safety education required under age 18 if taught in local school.
25 Required for age 14-15 and "motorcycle only" license applicants.
26 Two metro sites conduct off-street tests.
27 Under age 16.
28 In New York City and Nassau County, must be age 17 and have completed driver education.
29 Effective April 1, 1978, under age 18.
30 Age 14-16, restricted to 5 brake horsepower or less.
31 Driver education required regardless of age.
32 Under age 17.
33 Age 15 restricted to 100cc or less.
34 Only eye protection inspected.
35 Age 16-17, restricted to 150cc or less.
36 Two classifications, one for under and one for over 150cc.
37 Age 14-15, restricted license to and from work and school.

This information was assembled by the Motorcycle Safety Foundation Licensing and Law Enforcement Department. Licensing authorities in all 50 states and the District of Columbia were directly contacted by MSF for an update on the information listed in this chart.

Although this information was obtained from the most authoritative sources available as of December, 1977, the Motorcycle Safety Foundation is not responsible for its accuracy or completeness.

FIGURE 16: STATE MOTORCYCLE OPERATOR LICENSING PROCEDURES.

Data Element	Groups	NAS	Maryland
Accident Type And Location	Single Vehicle - Rural	23.0	15.0[1]
	Single Vehicle - Urban	24.6	24.0
	Multi-Vehicle - Rural	14.5	15.0
	Multi-Vehicle - Urban	37.9	46.0[1]
Collision Type	Pedestrian	1.7	1.1
	Non Motor Vehicle	3.5	0.7
	Fixed Object	7.4	NC[2]
	Ran Off Road	15.1	10.2[3]
	Overturned	15.9	17.8
	Other	12.6	7.0
	Head-On	4.1	3.5
	Angle Collision	25.1	47.3[4]
	Rear-End	14.5	14.2
Accident Severity	Fatal	2.5	1.3
	Injury	83.0	85.8
	Property Damage	14.5	12.7
Road Surface	Dry	91.3	87.3
	Wet	6.0	10.5
	Snowy or Icy	0.4	1.0
	Other	2.3	1.3
Light Conditions	Daylight	67.3	66.7
	Dawn or Dusk	5.3	4.8
	Darkness	24.7	28.3
	Unknown	2.7	0.2
Contributing Circumstances[5]	Driver Condition	26.7	1.0
	Human Behavior	38.9	75.7
	Environment	3.6	16.8
	Vehicle Condition	2.1	6.5
	Unknown	15.3	0.0
	None	13.4	0.0
Day of Week	Weekday	64.7	61.6
	Weekend	35.2	38.4
Hour Group	0101 – 0400	4.3	3.9
	0401 – 0700	1.7	1.2
	0701 – 1000	6.0	8.2
	1001 – 1300	11.7	9.6
	1301 – 1600	21.8	22.5
	1601 – 1900	27.5	24.8
	1901 – 2200	16.8	18.2
	2201 – 0100	9.4	11.7
	Unknown	0.9	0.0
Vehicle Type[6]	Passenger Car		88.6
	Truck		9.6
	Bus		0.6
	Motorcycle		1.0
	Other Vehicle		0.3
	Pedestrian		1.1
	Unknown		0.0
Sex	Male	95.6	98.6
	Female	3.3	1.4
	Unknown	1.0	0.0
Age Group	Under 20	40.4	28.7
	20 – 24	29.8	37.0
	25 – 34	18.8	25.1
	35 – 44	5.4	4.9
	45 – 54	2.3	4.0
	55 – 64	0.9	0.3
	Over 64	0.4	.00
	Unknown	1.9	0.0

FOOTNOTES:

1 The NAS File does not include such large urban areas as Chicago, Illinois and Wilmington, Delaware. Several other states are rural accidents only. This may explain the discrepancy between the urban and rural percentages and thus the single and multi-vehicle percentages.

2 NC – Not Coded

3 Includes those accidents classified as "Run (Forced) Off the Road"

4 Includes "Sideswipe" (11.6%) collision types

5 The NAS defines "Contributing Circumstances" as situations existing prior to the accident occurrence but which may or may not be immediate causes or indications of fault. All Maryland accidents were assigned some primary code which directly indicated the immediate cause of the accident. It is these percentages which appear for the item under Contributing Circumstances.

6 This item was not run for the NAS data. For the Maryland data, the distribution is that of multi-vehicle accidents and the type of the other vehicle involved in a collision with a motorcycle.

TABLE 14 COMPARISON OF NASF AND MARYLAND MOTORCYCLE ACCIDENTS BY NATIONAL ACCIDENT SUMMARY FILE DATA CATEGORIES

(Source: Motorcycle Safety Foundation 1974*b*)

The TRB has recently convened a task force on licencing under the limited aegis of the "driver" group of TRB Committees, which does not clearly relate to the other motorcycle and moped interests within TRB. There is as yet no "motorcycle" committee, unfortunately.

The MSF is now interested in an *Advanced* Course. Once again McKnight at NPSRI is working to NHTSA to develop the source material, and a final report on the curriculum specifications should by now be available from L. Buchanan at NHTSA. MSF wish to pick up the results, and both apply them and make them as widely available as possible under a formal Memorandum of Understanding between the NHTSA and the MSF. A different approach to testing itself is being developed by Atkins Merril Inc. for simulation and automated test procedures in Oklahoma City, and this and similar lines of work are continually reviewed by MSF for their possible contribution. The MSF also operate a Motorcycle loans scheme for safety education (MSF (undated, *c*)).

The MSF also keeps up to date on motorcycle safety statistics and has let a series of contracts to Biotechnology Inc.* on motorcycle user profile and accident data assembly. Table 14 is reproduced from MSF (1974*b*) and shows the relationship between the 50 000 entry U.S. National Accident Summary File and the 600 entry MSF-Maryland data base. The footnotes illustrate the usual problem of shifts in definition and focus between detailed and aggregated sources of accident data. Biotechnology Inc. are currently commissioned (MSF 1976) to develop a survey of motorcycle rider characteristics such as sex, age, experience, and education.

The MSF also issues literature aimed at the end user, and examples are given in MSF (1974*d,e,f,g*). A comprehensive list of all MSF publications and audio-visual materials is given in MSF (undated, *d*).

9. 57TH TRANSPORTATION RESEARCH BOARD - ANNUAL MEETING

9.1 MOPED SUB-COMMITTEE OF THE TRB BICYCLE COMMITTEE

Around 50 people attended this inaugural meeting of the Moped Sub-Committee (of the Bicycle Committee) of TRB. The terms of reference of the Sub-Committee were specified by Jim Williams, the TRB coordinator for Transport Safety. Such Committees are charged with monitoring activities, setting up areas of research need, preparation of research problem statements, data dissemination, and implementation. A substantial attendance list and minutes were made available after the meeting (Wilkinson, 1978). Ed Kearney (National Committee on Uniform Traffic Laws and Ordinances) stated that in a study undertaken in 1976/7 which analysed State Laws, those appertaining to mopeds were extremely diverse. The requirement for specific treatment of mopeds only arose in 1974, due to the very recent rise in importance due to vastly increased and accelerating moped sales. The Motorised Bicycle Association claim it is a unique type of vehicle, and 33 States have defined the vehicle in such terms. Although there were still only about 150,000 vehicles sold in 1977 the number is rising fast. Roger Quant (Director of Research of the Motorcycle Safety Foundation) mentioned the reactions of Consumer Product Safety Committees and specific plans to collect accident data by differentiating mopeds from motorcycles in reporting systems.

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* Biotechnology Inc., Falls Church, Va. U.S.A.

Herbert Miller (NHTSA's Office of Research) mentioned a moped handling characteristics research contract let to Dr. David Weir at Systems Technology International and also a problem analysis contract on moped issues granted to Bob Campbell at the Highway Safety Research Centre at the University of North Carolina. David Weir's project has an allocation of $US100,000 started in January 1978, and is due to report in December, 1978. Four types of vehicles, the Velo Solex, the Ciou, etc., will be tested. Computer simulations which *include* riders in the simulation will be carried over from the motorcycle dynamics contract for NHTSA now being completed. The NHTSA orientation of crash avoidance capabilities is likely to be emphasised. One side issue is the testing of moped tuning kits for their safety implications, as part of Weir's project.

A contract has been let by NHTSA aimed at identifying moped accident reduction measures and in consequence includes a problem identification and definition phase to be carried out by examining the experiences of other countries* to see how transfers to the U.S.A. of know how would be made (NHTSA 1977*b*). There is not yet enough accident data to formulate any well founded early action on legislative or regulative moped procedures in the U.S.A. This Contract is for $US80,000, started in February 1978, and is due to report in February 1979. Campbell intends to develop some projections of possible levels of use as part of the project.

A general statement made by many members of the group was that accident reporting forms are poor, and provide for no differentiation which would enable mopeds to be identified. Zimmerman (Motorised Bicycle Association) emphasised the heavy usage of mopeds by the 25-40 years of age group and the high percentage of female usage of these machines, although there are widely fluctuations from State to State. In Florida lots of old people use mopeds, and in California many young people do so: both utility and recreational usages are evident in high proportions in different States. Zimmerman has a fair amount of moped data on a State by State basis for many of the States.

The State of Illinois has encountered a number of real difficulties due to the rapid rates of change of user profiles for motorcycle usage. The 1965-77 profile shift has affected the Illinois Spring motorcycle training programs which are now being picked up by 40 year olds - with a high proportion of females - expressing a high degree of enthusiasm for taking the course. This does not accord completely with usage patterns. To assess and specify the size of this on going change in user profile was a critical element for moped assessments. Illinois also reaffirmed a point made by Wigan (ARRB) requiring Accident Cost values on an approved and vehicle specific basis in order to know what safety measures should be undertaken. New Jersey reported moped training in schools, although not to promote mopeds but to get rules of the road, etc. understood at an early, pre-driver stage in schooling. It was reported that the National CSPC Accident Data Base would be providing moped codes from April 1978.

The number of speakers mentioned that the mix of mopeds with pedestrians : cars : bicycles is not very well understood or covered in the U.S. Lew Buchanan of NHTSA reported that a task analysis for mopeds was being carried out to inform training and education course development just

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* The Netherlands has had heavy usage of both mopeds and bicycles for many years, and the Institute for Road Safety Research SWOV has published in the area (Kraay 1976). The adjacent country of Denmark is fairly similar and is covered by Engel and Lund (1973). Japan has also been covered by Honda (1977).

as was previously done with the MSF for motorcycles. Illinois reported that 130 courses had been carried out using Yamaha films and materials. The University of Southern Illinois has trained a number of high school and adult teachers in 33 counties in the State and are going to try several approaches: they are now fairly happy with motorcycle training but are not yet sure about mopeds. Roger Deane (Motorcycle Safety Foundation) reported that he had been doing a review of the U.S. literature on moped training and found little on the subject other than *motorcycle* specific reports. He also reported that a TRB Sub-Committee on Motorcycles had been set up from the Road User Committee for the *driver* area. The Driver Education Committee is now carrying out the function of an *operator* education committee. The meeting closed with requests for research statements to be sent to Bill Wilkinson who, in view of the heavy support for the Moped Sub-Committee and the high degree of activity at the meeting, requested a paper session on mopeds at the 58th TRB Annual Meeting in January 1979. Further Australian participation in the area would be specifically welcomed.

9.2 NORTH CAROLINA UNIVERSITY: HIGHWAY SAFETY RESEARCH CENTRE.

I met Forrest Council and Pat Waller of HSRC. Council reported that a motorcycle driver education course designed specifically for user and emergency skills (e.g. MSF Course) was under special study. They were aiming at 16-18 year olds and to their surprise had had some trouble obtaining volunteers in North Carolina. Funding levels also cut the number to half that hoped for in the original proposal. A surprising (and depending on viewpoint, possibly encouraging) finding was that very few of those who went through the skills training then went on to buy a motorcycle. This appears to be in direct contravention of the findings of Leon Robertson (1976*a*) at the Insurance Institute for Highway Safety. In two full years of operation 600 potential riders were trained, but only 30 subsequently bought motorcycles to ride. It is possible to trace accidents, mileage etc. for this small number, but there are as yet no street accidents to report! Similar work on cars has also been undertaken by HSRC, emergency skill development for 16 year olds both on road and off road range, with 3 years of experiment carried through already, has not yet showed up any initial differences between road and range training: this is still under study and cumulative statistics are being built up.

Waller supplied a copy of her revised paper on the use of motorcycle headlights during the day (Waller and Griffin, 1977).

9.3 EVALUATION OF MOTORCYCLE DAYTIME HIGH VISIBILITY AIDS: ASHFORD, STRAND, KIRKBY, KIRK.

This paper (Ashford *et al.* 1978) is the first public report of a long running research project at the Loughborough University Institute for Consumer Ergonomics in the U.K., sponsored by the U.K. Transport and Road Research Laboratory over the last three years. Quoting part of the abstract:

> "This paper is based on the first three years of a continuing research project investigating the performance of conspicuity aids for motorcyclists and user attitudes towards such aids. It reports on the results of a volunteer consumer attitude survey to overjackets, waistcoats, sleeves and slipovers, which have led to new designs now under evaluation."

This pragmatic work provides a useful numerical basis for reviewing the consumer attitude towards "visible" clothing. A telling point is that even amongst the volunteers for this experiment, just over 25 per cent admitted to embarrassment caused by color, material, or styling of the safety clothing involved. This is further emphasised as 18.6% of the respondents had previously worn such clothing before, as against the usage level of 1.5% for the observed motorcycle population.

19 Items of visible clothing were tried, and were rated by the users after field experience in terms of -

(a) Length of the garment

(b) Speed exposure

(c) Inconvenience at maximum speed

(d) Rippling due to wind stress

(e) Interference with riding

(f) Ease of cleaning.

None of the garments were rated at "good" or "very good" for all items, but 75.5% of the respondents were still wearing their garments at the end of the three month period. Over half of those who had stopped had done so in the first month. Of the 25% who stopped, over a quarter had done so because the garments were too troublesome or inconvenient, and 20% because they no longer had a motorcycle.

One of the complementary studies was to carry out Laboratory simulations of the effectiveness of high visibility aids at a simulated distance of 92m. This choice of a long distance appears to have required extensive data collection and anlaysis to obtain a significant ranking of mean detection times for different measures, and may be compared with the techniques and results of M.J. Williams (1976) and Williams and Hoffman (1976).

A further complementary field study attempted to measure gap acceptance behaviour, but the results are not presented in sufficient detail to determine the significance of the findings. Olsen and Nusloch at HSRI are presently carrying through a similar study covering a wide range of manoeuvres for gap acceptance, but this is not yet ready for publication.

10. SYSTEMS TECHNOLOGY INTERNATIONAL, LOS ANGELES

10.1 DAVID WEIR

STI has an international competence and reputation in automotive design and testing (STI 1977). Dr. Weir has been connected with motorcycle, car and truck handling for a considerable period of time. Systems Technology International is heavily involved in vehicle controller plus vehicle simulation systems analysis which ranges from aircraft to ground transportation. Weir's doctoral thesis at UCLA was on motorcycle handling (Weir 1972). Part of the current NHTSA project on motorcycle performance was to review the anti-lock braking system of TRRL. Jeff Meades and the Norton Commando equipped with the Mullard TRRL anti-lock system front and rear flew over from TRRL to California for a brief two week testing appraisal period in 1977. The anti-lock brake application tests were carried out both for straight ahead retardation and for braking in turns. Only a small subsequent effort (of about one man week) was available to be spent on the concepts of anti-lock braking and their applicability as illustrated by the TRRL machine. The concept was confirmed to be good in principle and therefore becomes in Weir's view a question only of engineering costs and user application. Weir was favourably impressed with the TRRL system.

The next major international review of motorcycle safety was the 1978 SAE Congress in March where a full day was spent on motorcycle safety. Weir spent around a year with Roy Rice of CALSPAN in planning and supporting this SAE session and it was intended to provide a complete coverage (Weir, 1978).

An expert local competitor (John McKibben) has his own local consulting automotive engineering firm in Los Angeles and has worked in concert with Weir resolving local problems for America Honda (Gardenia). The NHTSA Request for Proposal forwarded to me by Professor Haight on "a rear wheel steered motorcycle" was confirmed to have been issued, and the $80,000 allocated has been awarded to Southcoast Technology Inc., at Goleta Santa Barbara. Some notes on the form of this proposal are held (Anon 1977).

The progressive development of STI motorcycle simulation systems starts with a purely lateral steering simulation which was very simple, somewhat old, and never published. It was a linear simulation written for a DEC-PDP 10 in FORTRAN 4 in the *spatial* plus transfer function domain. The second stage considered the time domain with digital non-linear integration. This has also been written in FORTRAN and is still under development and is required as part of the report by the currently terminating NHTSA contract on motorcycle dynamics. STI already has the solutions for the linearised results for handling, and at particular points can cross validate the linear against the non-linear simulation rather than needing to go right back to data. It is a generalised non-linear simulation model similar to that previously built for trucks and buses at STI. Some of the results were reported in Weir (1978) which also includes a bibliography on motorcycles and handling including rider behaviour dynamics and other two wheeled systems. The Japanese were invited to (but chose not to participate in) the SAE meeting, so the most recent documentation of their work is only to be found in the Washington 1975 Proceedings (NHTSA 1977*a*). At a later meeting on STI premises we met Dr. Weir and his collaborator Wade Alan. The main current effort at STI is aimed at cars using analog simulation with a video generator, and is led by Steve Schwartz. The team will shortly move on to truck problems. A recent study examined the effects of areodynamic disturbance on cars passing trucks (Heffley 1973; Weir *et al.* 1974). This particular project made use of digital simulator calculations although the basic simulator remained the STI analog system. A further study just completed is the use of multiple tasks to check the effects of avoidance. This simulation system has been validated against full scale tests on decision making and response for alcohol intake.

STI now have video display generators and can therefore simulate visibility conditions. They can also add posts, edges, lining fog, etc. The size of road markings, obstacles, can be made to pop out and to perform other variations. The signs are introduced by slides projected through a zoom lens and reflected by a mirror rotating under a coupled servo drive motor. The whole simulator is very simple and perhaps possesses as little complexity as could reasonably handle the task with some degree of realism. Were it not for the continued STI program of validation studies against which the simulations are checked, one might consider that the simulator would not be terribly effective. A somewhat simplified STI analog simulation system was recently sold as a single rack to Mortimer at Illinois.

Weir's collaborator concerned with motorcycle digital simulation is Gary Teper. The motorcycle and rider simulation being completed for NHTSA started with 19 degrees of freedom covering wheels, swinging arm, frame centre block, frame top segment above the suspension, frame lower segments below suspension, all angular planes, and fort torsion. It should be noted that it has already been determined that unless the motorcycle is very small (i.e. smaller than a 125 Honda) the upper body does not have much effect. A simplified approximation has therefore been adopted reducing to two purely mechanical degrees of freedom plus 6 mixed controls giving three control logic loops (Weir and Zellner 1978). This was to be used in the moped evaluation program for NHTSA during 1978*.

Gary Teper is finishing off five years of work on a biomechanical model of the complete body, including perceptual, muscular, and the ride quality assessment factors (Jex *et al.* 1978), (e.g. this will naturally have application to most vehicles and not solely to motorcycles).

Aerodynamic effects on the three major masses and the coupling of several of these is included in the general motorcycle simulation. One example is that handlebar mounted fairings affect damping torque for steering, and dynamic damping: an issue of considerable concern to A.C.T. police (House of Representatives 1978). One option included in the program generates a linear variation about a pivot point (e.g. disturbances imposed on a steady turn). The motorcycle tyre is being included as a specific tyre model, and there is now fairly complete data and detail due to work CALSPAN has carried out. CALSPAN's (Rice 1977; Rice *et al.* 1975, Roland 1974, Bartol *et al.* 1975) comprehensive study covered design camber angles for large amplitude limit manoeuvres, mainly for a 360 cc Honda on stock tyres with wire wheels. The data gained on forces and 3 axes is included in the tyre model incorporated in the new NHTSA simulation system written by STI. Data is also available on the moments about 3 axes, but this is not as yet included. The main validation checkout procedure for the STI simulation is to be by using an analytical linear motorcycle model which will provide a tight check of the linearised eigenvalues. The $\underline{\dot{X}}$ matrix representation throws up acute problems with widely scaled eigenvalue ranges: the routines are stable over $10^{4:1}$ range but are still pressed by the values thrown up in practise. This covers ranges of 0.1-1000.0 intervals per second. It is set up on a DEC-PDP 10 and may have to be taken over to a Control Data system to obtain full word length precision: a very rare necessity. The coefficient matrix is sparse at a density of less than 50 per cent. Graphics output will certainly be used using an XY hard copy plotter in order to resolve the data and reduce it to manageable format. When the NHTSA project is in final documented form Weir will send full details.

Weir considers that the information is now available to recommend limits between response times and steering angle for *motorcars* as advisory limits on vehicle design (Weir and Di March 1978; Weir and Zellner 1977). There are two regions of response and reaction time for experienced and for inexperienced drivers and there is a large overlap area within which both are satisfied. There are also boundary areas in both axes which appear to be fairly well established. Weir would not consider that the same could be achieved for some years in the motorcycle area. Recent developments

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* A recent report on moped and bicycle handling dynamics was produced by SWOV in 1975 (Godthelp and Buist 1975).

with the new Dodge Omni and Plymouth Horizon small vehicles are now pressuring NHTSA to develop a government standard for vehicle stability (Economist 1978).

11. CALIFORNIAN DEPARTMENT OF MOTOR TRANSPORT

11.1 RAY PECK (RESEARCH PROGRAM MANAGER)

Peck is the Research Program Manager of the R. & D. Section of DMT, and we met in Washington during the TRB meeting. The activities of this research program are:

1. Driving Licence Tests. Audio visual including active programmed learning control procedures.

2. A very large project on drunken driving on licence suspension with rehabilitation possibilities.

3. Habitual traffic offenders attitude changing, using warning letters. Self-learning kits, group meetings and individual counselling with before and after research studies to assess the effectiveness of the measures tried.

4. The major study of special interest is the motorcycle driver licencing project being carried out under the direction of Jack Ford at sites in both San Diego and Sacramento.

So far 24,000 pupils have passed through but a total of 36,000 will be needed for the full series. The basic design is that if a test is failed, retraining is required before the pupil is eligible to sit for or pass further written and driving tests. The written test for this second group has been scaled to be very discriminating. It was developed by Jim McKnight at the National Public Safety Research Institute*. The Californian DMT's have interpreted their administrative powers to give mandatory force to the random allocation of prospective testees to three groups:

Group 1 requires no special action (i.e. the present official licencing procedure).

Group 2 takes the more stringent version of the Motorcycle Foundation Rider Test that California has adopted, plus NPSRI written test (Fig. 14 is the test scored for the author).

Group 3 undergoes a six hour remedial training course including hazard avoidance training.

It should be noted that a fair percentage of the 24,000 people have already gone through other training systems previously, sometimes this is even the Motorcycle Safety Foundation Course. A questionnaire which picks up vehicle miles of travel etc., is administered to all participants. The initial tentative conclusions which seem to be emerging are that only a difficult test plus hard training seems to actually affect the subsequent accident performance of the riders. However, the 24,000 so far processed and the brief length of time that has so far elapsed means it is essential to continue the experiment for the further year scheduled originally and review all the aspects of operation results, and follow-up incidents more closely before any unequivocal conclusions could be firmly drawn on this or other issues.

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* Alexandria, Washington DC.

EXHIBIT A

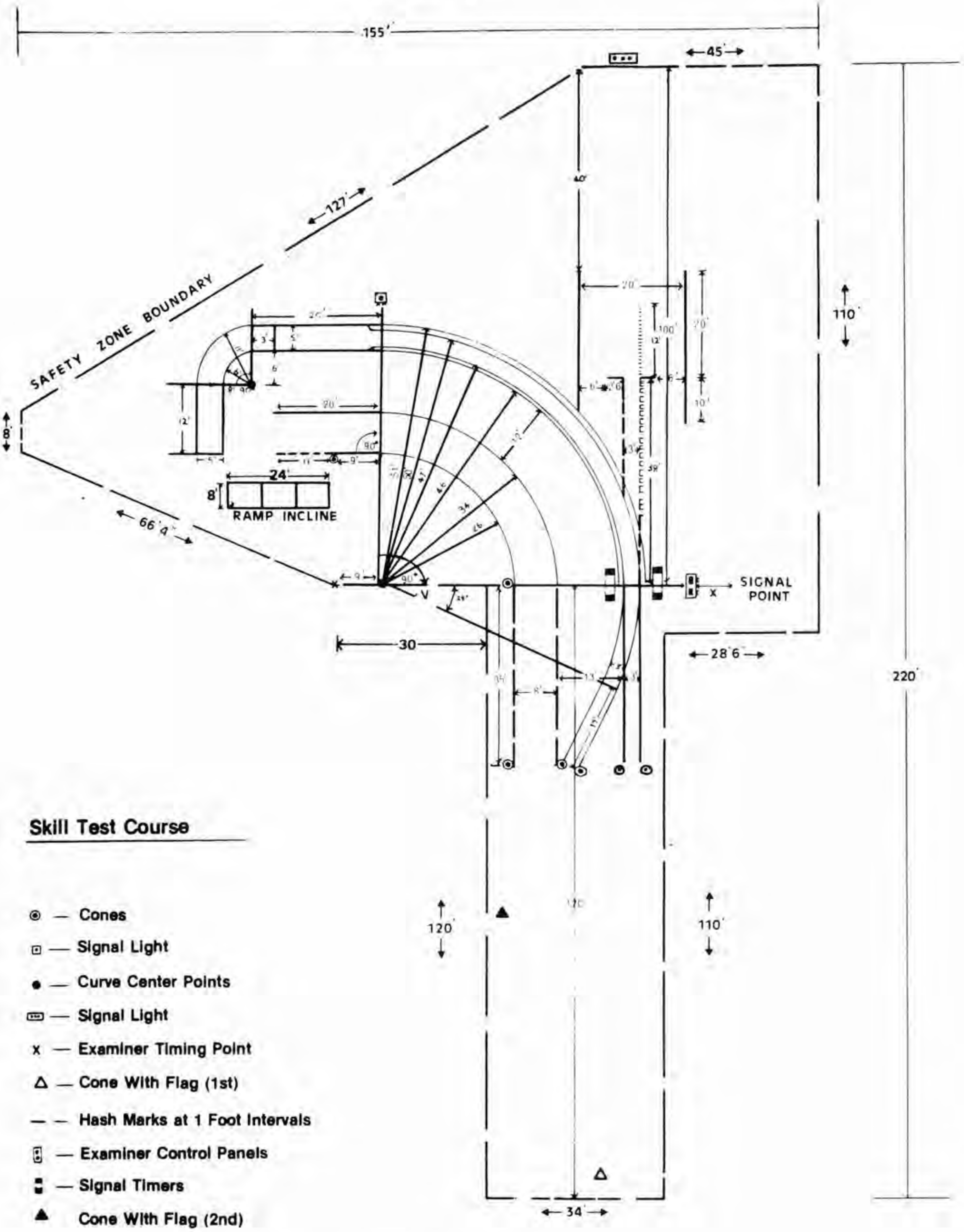

FIGURE 17: SKILL TEST COURSE

(Source: Motorcycle Safety Foundation 1976*a*).

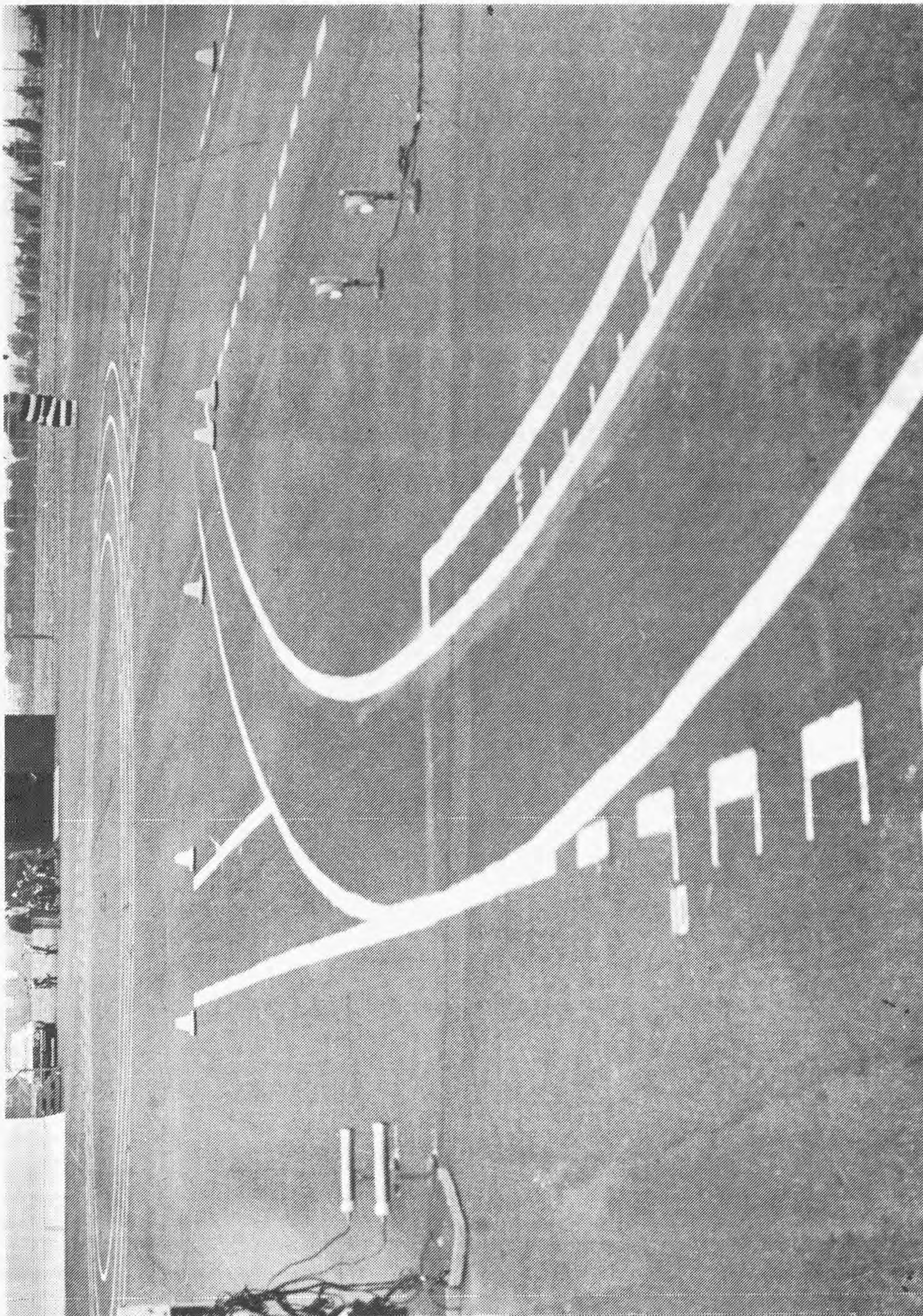

FIGURE 18: CALIFORNIA DMV - SACRAMENTO MOTORCYCLE TEST RANGE

11.2 JACK FORD, PROJECT LEADER (MOTORCYCLE LICENCING PROJECT)

Later in my itinerary I went to the Sacramento site where the Motorcycle Licencing Project was being operated. Bob Norris is the Range Manager at Sacramento. The Sacramento Range is 60 m x 120 m in size. The Californian Highway Patrol originally wanted an unpaved area. This proved to be unnecessary and in fact meant that the reserved area was larger than need be. The range is located way out in the outskirts of Sacramento in the freighting and open storage areas. The area specified includes offices, storage for machines, marked training and testing areas, and permanent Installations. In the 3 hours training on the range the precise remedial targets are braking and avoidance to in and by turns. The San Diego range is slightly larger at 64 m x 120 m. The range surface is a slurry seal on an asphalt base. Grass growing through appears to be a minor problem, and the cold rolled asphalt base bubbles and cracks. Drainage also gives some problems. Utility access for power and water and lighting level problems have also proved to be difficult to resolve and 1 foot-candle has proved to be the lower limit adequate for reliable night or evening work. Reports on the motorcycle licencing project included a 1976 Preliminary Report (California DMV 1977) but the 1977 Annual Report contains a very substantial amount of substantive research. The research for this is expected to have been completed by April, with June as the target date for publication. It is expected to be a material document. The Final Report is due in September 1979 to the sponsors, the National Highway Traffic Safety Administration. The essentials of the special layout are shown in Fig. 17, and a photograph of the actual site is included as Figure 18.

The motorcycle licencing project was originally planned as a joint exercise between the Californian Highway Patrol, the Department of Education and the Departments of Motor Vehicles. Unfortunately the Department of Education required a minimum of 24 hours tuition, and when it was clear that a 6 hour course (3 hours class, 3 hours range) was in prospect were therefore no longer able to form part of the consortium. The Californian Highway Patrol hires out officers to the project for training purposes, and thus provides a severely practical teaching input. At this stage in the project this is the sole substantial continuing involvement.

The normal vehicle licencing ages in California are 18 year of age for all vehicles. An alternative that is encouraged, is licence issue with parental consent, conditional on passing an approved driver education course, a licence can be issued at the age of 16 years.

I took the DMV test (See Figure 19) on one of the ranges and used a 125 cc single cylinder road Honda, although I did not go through the course itself. Riders may use Range machines or bring their own. It was abundantly obvious that it was essential to use a speed measuring device to calibrate the speedometer as part of the normal test procedure. The avoidance exercises I found genuinely difficult; it should be noted that my motorcycling experience is substantial, covers 20 years of road riding and 11 of road racing at all levels of competition. The braking in a curve test is equally awkward*. It should be noted that the test actually provides a genuine test of capabilities and skill, and therefore could be expected to appeal to the ego of motorcycle drivers in that passing the test has something to commend it in terms of achievement of which they can be proud. A rider who came in for a test riding a modified 750 cc Honda was clearly regarding it in this light. Every exercise has a standardised

* Figure 13 shows the layout of the key area on the range.

1. Driver's License, I.D., or App. No. (8) AUSTRACIA
2. Today's Date (Month, Day, Year) (6) 0 1 / 3 1 / 7 8 9–14
3. First Three Letters of Last Name W H I 15–17
4. Test Attempt (Circle) (1) 2 3 18
5. Engine Size in CC's (4) X125 19–22

MOTORCYCLE STUDY
FORM 6

NEW MOTORCYCLE SKILL TEST

TO APPLICANT: Failure of any maneuver is grounds for immediate ending of the test. Also you or the examiner may terminate the test when it is felt that the next maneuver cannot be completed safely. The test is automatically failed if you accumulate more than 12 points.

APPLICANT'S SIGNATURE

TOTAL POINTS LOST -2

	FAIR	POOR	FAIL	TOTAL POINTS LOST	EDP COL
1. STARTING AND ACCELERATING ON A HILL	•	•	•	•	•
A. Start/Stall	1	0	5		20
B. Backward Roll	•	3	5		21
C. Feet During Movement dub	(1)	•	•	1	22
(1.) Pass 2. Fail	•	•	•		23
2. SHARP TURN	•	•	•	•	•
A. Path	•	3	5		27
B. Feet	•	1	•		28
(1.) Pass 2. Fail	•	•	•		29
3. TURNING CONTROL–RIGHT	•	•	•	•	•
A. Path	•	3	5		30
B. Time 9.7	1	3	5		31
(1.) Pass 2. Fail	•	•	•		32
4. TURNING CONTROL–LEFT	•	•	•	•	•
A. Path	•	3	5		33
B. Time 5.7	1	3	5		34
70 (1.) Pass 2. Fail	•	•	•		35
5. STOPPING JUDGEMENT	•	•	•	•	•
A. Smooth Stop	•	3	•		36
B. Stopped Position	•	•	5		37
(1.) Pass 2. Fail	•	•	•		38

	FAIR	POOR	FAIL	TOTAL POINTS LOST	EDP COL
6. TURNING SPEED JUDGEMENT	•	•	•	•	•
A. Time 2.0	1	3	5		39
B. Path	•	•	5		40
(24) (1.) Pass 2. Fail	•	•	•		41
7. QUICK STOP STRAIGHT	•	•	•	•	•
	•	•	•	•	42
A. Time 105 ms	•	•	•	•	•
Distance 26	1/2	3/4	5		43
36 (1.) Pass 2. Fail	•	•	•		44
8. SIGNAL TURNS (L or R)	•	•	•	•	•
A. Course Time 100	•	•	5		45
	•	•	•	•	46
(1.) Pass 2. Fail	•	•	•		47
9. QUICK STOP CURVE	•	•	•	•	•
A. Braking Path	•	3	0		48
	•	•	•	•	49
B. Time 164 , 152 ms	•	•	•	•	•
Distance 18 , 19	(1)/2	3/4	5	1	50
(18) 1. Pass 2. Fail	•	•	•		51
10. EXAMINER BADGE NUMBER	•	•	0229		52–55
11. Pass Fail	(1) Pass	2 Fail			56
12. Scheduled for Training	1 Basic	2 Advanced	(3) No		57
13. Did Applicant Wear His Own Helmet?	1 Yes	(2) No			58
14. Accident On: (0) 1 2 3 4 5 6 7 8 9					59
				SKIP:	60–76
15. Card Type				07	77–78
16. Study Code				56	79–80

DL 200 (REV. 7/77) M/C PROJECT

FIGURE 19: CALIFORNIA DMV - TEST PROCEDURE FORM.

performance table of the type shown at Table 15. As will be noted from the test sheet diagram, the standards are automatically equalised for variations in user entry speed into the exercise. The "Time" column refers to the interval elapsed on the electronic clock triggerred by the photocells visible in Figures 18 and 19.

Exercise 9 Curve

Time/Distance Chart

Time	Standard Feet
.110-.112	31
.113-.115	30
.116-.119	29
.120-.122	28
.123-.125	27
.126-.128	26
.129-.132	25
.133-.135	24
.136-.138	23
.139-.142	22
.143-.145	21
.146-.148	20
.149-.151	19
.152-.153	18

TABLE 15 : SCORING CHART

(Source: Motorcycle Safety Foundation (1976*a*)

The lecture procedure is excellent. The slide show is an alternation of real world accident situation slides with pictures the particular manouevres in the training program relevant to avoiding that particular type of incident. When it is realised that the Californian Highway Patrol motorcycle patrol policeman are giving the lectures, it is not surprising that a fair degree of communication is achieved as forceful anecdotal reinforcement of any point is readily available. Lecturing normally starts at 6.00 o'clock in the evening.

During the rider training they use Honda supplied *reflective* vests (Note: *NOT fluorescent*). An interesting practical point is that it is necessary to warm up the motorcycles during the lecture session otherwise a very large amount of time tends to be lost from the on-range teaching period.

The CHP Lecturers genuinely achieve a very practical communication with the students as they can go on for hours about real situations in which avoidance is necessary. Originally the intention was to use video-tape lectures, but this did not work out very well in practise. They also originally used the Honda 200 static belt-driven test track (this is a simulated road a moving belt with the motorcycle on it) in order to get instructors to check out prospective pupils on their actual ability to operate the controls. This proved in practice to be rather dangerous, with too many problems. This procedure requires considerably more development before such a practical use would be sensible, although it is reasonable to expect that this could be achieved. The Californian Highway Patrol certainly seem to be fairly happy at the discouragement aspect of the harder test, which is sufficient to reduce some of the less safe or confident riders from proceeding. The slide sequence has sufficient impact that the American Motorcycle Association asked for a set for their own safety promotion use. I also asked if a set could be supplied.

At the planning stage, everyone was worried about the potential problems of persuading people to go to the range as it is a long way out - in practice many people have to be turned away as the experimental design demands it. This seems to confirm the hypothesis that this tougher test would appeal to the generally high ego involvement of motorcyclists with their machine and its' skilled operation.

The Department of Motor Vehicles in the State of Tennessee has an in-traffic car following (motorcycle) licencing test procedure which impressed Ford when he saw it. Jim McKnight at NPSRI has developed a special test for the Department of Motor Vehicles, California, and is also working on the Tennessee 'following test' procedure at present.

12. UNIVERSITY OF SOUTHERN CALIFORNIA

12.1 PROFESSOR H. H. HURT JR. (The Institute of Safety and Systems Management)*

Professor Hurt is responsible for a major NHTSA in depth study of motorcycle accidents in Los Angeles, and as 900+ such accidents had by the time of my visit been collected but not fully analysed, only initial and indicative conclusions could be discussed. It should be clearly understood that the opinions expressed by or attributed to Professor Hurt's group may well be revised substantially in the detailed final report when analysis has been completed and clean data tapes made widely available.

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* Los Angeles, California 90007, U.S.A. : Tel (213) 746-6525.

None of the comments which follow should therefore be taken as being definitive answers from this project, as the analysis is a question of a major and continuing effort on a substantial scale and most of these conclusions are tentative and drawn solely from the cumulative experience of the investigators involved.

Nicholas Tsongas* and Clay Hall of NHTSA are managing the study from Washington for NHTSA. The study area is the County of Los Angeles. This includes the city of Los Angeles and all of the surrounding segments within the county which includes urban, suburban, rural and even a small amount of mountainous country. 917 motorcycle accident cases had been investigated in the period from beginning of January to end of December, 1977.

My first inquiry was on the subject of the effectiveness of tank bags as a preferred means for carrying luggage (they are immensely popular for long fast journeys frequently undertaken by motorcyclists in the Continent of Europe), and could not be answered as the Motorcycle Industry Council had decided to promote the use of luggage carrying equipment only behind the passenger. This decision could possibly have failed to note the centre of gravity shift effects on stability**: such effects are virtually obviated by tank top luggage carrying. Unfortunately this particular in-depth study can shed no light on this area. In the accidents which have been analysed so far, the time from the precipitation of the event to the actual impact has been coded in units of a tenth of a second: the median such delay for the accidents analysed so far is 2.2 secs. - about 14 m at the median speed of the USC set of accidents: technically a sufficient distance for really strong braking to bring the machine to a stop in many cases, which leads to a special interest in antilock braking and overcoming the propensity for many inexperienced riders to fail to use the front brake to anywhere near its' potential in accident situations.

One of the procedural details of special importance to motorcycles is that the surface friction on the road at the accident site is measured using a special drag wheel procedure measuring μ exactly on the wheel track of the accident. This appears to pick up the factors of 2 in accuracy which have been shown to have been lost previously for single track vehicles when this procedure was not followed. There appears to be little correlation between the μ values now obtained and the skid number based on the SAE smooth tyre test. In order to avoid bias as a result of oil and fuel spillage in the course of the accident the tyre used for the μ test is cleaned with chlorinated napthalene before each and every measurement.

One of the anecdotal initial findings is that there is a strong tendency by accident over-involved users to overbrake with the rear and to underbrake with the front compared to the braking performance of the vehicle itself. A typical intersection accident involves a rear wheel skid. This accords with Australian experience, and in the subject of a specific training and testing recommendation by the Parliamentary House of Representatives Road Safety Committee (HOR 1978). Some of the mechanical devices developed to assist riders include the Moto Guzzi linked braking system: this actuates one front disc and one rear disc when the foot is depressed and the other front disc is controlled by the handlebar lever. The Police Department of Los Angeles very positively dislikes these linked brakes: they are, however, strongly approved of by many motorcyclists and other police agencies.

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** See for example Roe and Thorpe (1976) for a lucid analytical demonstration of this effect, confirmed by their experiments. Also Section 8.1 of this report.

Numerous accidents in Los Angeles involved severe fuel loss. This places a heavy emphasis on the progressive removal of fibreglass tanks from machines sold although it must be remarked that in very few cases did a fire start in these accidents. Polypyrolene (a form of plastic) and aluminium, and steel tanks seem to be preferred. This is one of the initial anecdotal findings which may well be modified by careful subsequent analyses.

Some comments on protective clothing based on the 384 accidents so far coded onto the tape at the time of my visit showed the extremely large effects of safety helmets on fatalities and injuries, and neck injuries in particular. Due to the American Bill of Rights, it is no longer a legal necessity to wear a helmet in California. Only about 50 per cent of those using motorcycles in the study were wearing helmets when the accident occurred. It should be noted however that only 30 per cent of the accident-involved riders were wearing helmets. Consequently, there is a strongly indicated degree of self-selection of safety equipment by the more safety conscious riders.

Single vehicles are strongly over-represented in the fatal accidents. Other in-depth studies in Los Angeles have shown that 55 per cent of accidents involved alcohol on the part of the participating drivers. An identical figure (of approximately 55 per cent) appears to have been confirmed in the motorcycle study as well. It should be further noted that *non fatal* motorcycle accidents have an extremely *low* alcohol involvement: a finding consistent with Australian results (Williams 1977). Alcohol appears to be a signature of a *fatal* motorcycle accident, be it by increased vulnerability, lack of response, or otherwise. In view of the high vulnerability factor of motorcycles there is an indication here which should be pursued, given the control group of those involved in non-fatal accidents where the alcohol is low: alcohol may increase *vulnerability* as well as performance.

One initial observation on conspicuity* which will be examined carefully by the team in the detailed analysis phase is that at the date of my visit not a single *intersection* incident had been encoded** with the rider involved wearing a "Visible" jacket (i.e. *either* fluorescent *or* reflective). There are several interacting elements of self-selection of the population at risk in this area, but it is of definite interest to point out the low number of such incidents. Initial study of conspicuity accidents at intersections where the other vehicle approach zone was between 11.00 - 1.00 o'clock (i.e. ±30° head on closing angles) showed that motorcycles with headlights on were strongly under-represented in accidents. Consequently there is some further indicative evidence to confirm that daytime use of motorcycle headlights is a genuine countermeasure for *head on* incidents - as long as the results hold up when converted for the self selected population of users who voluntarily use headlights during the day. Precisely the same finding seems likely to be confirmed for motorcycle fairings with the same proviso. For the numerous intersection incidents in the range *excluded* by 11.00 - 1.00 o'clock (i.e. the remaining 300° zone) headlights have very little effect - as might have been expected.

Night time usage of motorcycles is comparatively low in Los Angeles: 90 per cent of all accidents logged in the study occurred between 12.30 a.m. and 6.30 p.m. Night-time accidents had higher levels of alcohol involvement and a considerably larger proportion of smaller machines and mopeds indicating a different user population were involved.

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* A Japanese expert in this field was named: Atazuke of Honda R. & D.

** not all accidents had been fully encoded for these factors at the time of my visit.

Some initial findings from the limited range of helmets so far analysed were discussed. Polycarbonate helmets appear to be involved in more injuries to the base or rear of the skull. Whether this was due to the greater number of open face ("jet" style) helmets made in polycarbonate or not, there is no way of telling at present. However, the use of full face helmets makes a really big difference - in a favourable direction - in terms of the injury scale rating of the damage met with by the users. The speed distribution of these (predominantly) urban accidents has a median value of 50 km/hr, indicating that even the comparatively low impact standards of FMVSS 218 (i.e. Z90.1-1971) are not inappropriate for a large percentage of the accidents covered in this urban-dominated study. It is confirmed by the FMVSS 218 markings on the helmets which appear to correspond to a fairly good operational standard in these predominantly low speed circumstances* (average impact 50 km/hr). This finding is in agreement with similar Canadian studies (Newman 1974).

In view of the special interest in the biomechanics and epidemiology of injury incidents, Hurt has developed with the Los Angeles Coroner a careful cooperation in a specialised autopsy procedure. This started in the 1st January 1978 and will therefore have contributed to some of the accidents now being studied. As about 300 motorcycle fatalities are expected in the Los Angeles area within 2 years, the special autopsy procedure to analyse head and neck injuries and upper spine effects will rapidly show significant results. This could quickly provide sufficient data to decode on the accuracy of the hypothesis put forward by Dr. Yeo (House of Representatives 1978) on full face helmets and paraplegia incidence. It will also provide further evidence on the contention that helmet use exacerbates neck injuries: a proposition of doubtful validity (Lynn 1978) but frequent anecdotal reference.

The color of the motorcycle, as distinct from the color of the helmet, also shows up in accident involvement propensities as blue and black are over-represented in accidents and red is three times under-represented on the same scale**. Clearly this is an observation associating color *choice* by purchaser with accident propensity in view of the very small visible area subtended by the coloured area on the motorcycle.

The plans for the next stage of analysis in this NHTSA project and associated work at USC include:

1. To analyse the motorcycle data.
2. To continue the in-depth study of fatalities in Los Angeles with the newly agreed autopsy procedures.
3. To concentrate on exposure data analysis and correlation from the NHTSA study.
4. To initiate a study of moped involvements in road accidents, exposure, and populations at risk.

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* Two systematic helmet testing studies are worth noting in this connection: Scalone and Damis (1972) report on 132 tests to the then-proposed FMVSS 218 noting the importance of a good fit for reproducible results, and Gillies (1976) which indicate *inter alia* that Z90.1-1971 and AS 1698-marked helmets show up well in the wide variety of protection levels found in helmets on sale in N.S.W. 1971-76.

** JAMA (Japan Color Research Institute, 1974) have investigated the effect of various motorcycle colors, and found yellow and red to be slightly better than other colors.

Currently the costs in the present study leads to a value of about $US400 per accident including the subsequent analysis and validation involvement. Approximately $US150 of this is for exposure data. Exposure data is collected at every site where an accident has occurred, and the number of edit procedures through which the data is taken is producing a reasonably substantial and certainly carefully edited data base.

Leg injuries show that crash bars may be of some assistance in one half of the cases and aggravate injury risk or severity in the other. There is a lower incidence of AIS 3 injuries for certain machines to which the basic design provides automatic semi-crash bar protection to some degree. The machines of this type picked up in this study are Moto Guzzi range, the Honda Gold Wing model, and the BMW range. Each of these do indeed show up to positive effect, and in addition the crash bars fitted by the manufacturer to reinforce the protective potential of the V twin cylinder heads on the Moto Guzzi appear to provide a positive advantage. BMWs involved in side impacts can completely wipe out a car's suspension or front grille - and in practice *do* appear to save the riders leg while doing so. The BMW is a flat twin with extremely massive horizontal cylinders. Clearly crash bars must be taken in conjunction with the engine layout and detailed machine design before reliable conclusions for road user safety may be drawn.

Defect analyses are a matter of special concern to NHTSA, however the sealing performance of gas tank filler caps is the only specific issue which has shown up as significant at this stage of the initial analysis. The Honda CB 750 "Monza" type of gas tank cap has been involved in a very high percentage of the fuel spills recorded. It should be noted however that the later models of CB 750 (the F1 and F2 series, as distinct from the previous K series) and the large Honda Gold Wing models are excellent in this respect and perform very well*.

Maintenance defects *do* show up but only to the extent of showing that mechanics in shops do not necessarily assemble or reassemble machine components to appropriate torque settings in pre-delivery or post-overhaul stages. Strictly speaking this is *not* maintenance but more in the domain of machine preparation and professional standards, and it is not unduly surprising that motorcycle shops are at this stage rather more to blame than owners in view of the recreational nature of the predominant part of U.S. motorcycle usage (unlike moped usage in the U.S.A. which is growing rapidly and with a utilitarian flavour).

The Computerised Accident Reconstruction Program was recoded by McHenry after its initial release and it is now set up to get pre-accident speeds with a probability distribution of the size and estimated direction. CRASH includes an impact simulation option Simulated Model for Auto Collisions (CMAC) which was written by Hurt's group at the University of Southern California. The CRASH program has been used for some time at USC for accident data synthesis. USC is now extending the CRASH logical schema to cover motorcycles. It is a complex option but standardisation in analysis and presentation in reduction of the data will be materially assisted by extending and using CRASH this way, and its use will considerably help synthesis.

The speed of impact in every accident studied is estimated using the Calspan CRASH reconstruction programs which costs approximately $US20 computing time per incident (McHenry *et al.* 1976).

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* A Japanese expert in this area was named: Yamamoto of Honda R. & D.

The target date set for the completion of preliminary analysis was May 1978. In addition to the 917 cases with exposure data on every site, Hurt's team at USC has collected 4000 ordinary Traffic Accident Reports for accidents occurring within precisely the same area for later cross-correlation purposes. To assist in the design of the study 5000 accidents were checked in the year previous to the start of the NHTSA study. Dr. James Oneliot - the human factors specialist on the team - remarked that there were extremely few pedestrian involvements and this too had an influence on the NHTSA/USC study design.

Some initial indications are apparent for moped usage (which rose substantially during the study period). Although mopeds are not legally approved for passenger carriage in the U.S.A. (although this is common in many other countries), the massive exposure data collected shows a considerable number of person-carrying accidents and therefore confirms that passenger carrying on mopeds is already significant. It should be noted that California has adopted the same year of qualification for moped and for car driver licence issue. The initiation of a special study on this moped data was scheduled for June 1978.

This NHTSA sponsored USC study was then put into the context of the National Accident Sample Survey throughout the U.S. NASS aims for about 60 centres for multi-disciplinary sampling units. This should be completed by 1982 and should overtake the many one-offs (e.g. the NHTSA study under discussion). Qualtiy, standardisation, and sampling control have not previously been worked out on such a scale: this is NASS's main objective and will require substantial amounts of training and a high degree of uniformity in coding. USC - and Hurt's group in particular - is very active in these areas and have done such training for many years: consequently many of the staff in the NASS teams were originally trained at USC. The need for NASS is emphasised by the meticulous assessment of definitions, coverage, and comparability of motorcycle accident statistics carried out by Winn (1978).

It should be noted that the entire team including the Principal Investigator (Hurt) are skilled experienced motorcyclists in addition to their profession as accident analysts. This aspect of the team was stated to have proved to have been a necessity rather than a luxury by this stage of the study.

Some interesting third party involvements have already emerged from the analysis to date. Animal involvement is high (at around 2-3 per cent of all accidents) and is considerably higher than all pedestrian involvements. Pedestrian involvements in their turn are rather low, but even so are considerably higher than motorcycle accidents wth any fire involvement. This puts the importance of gas tank sealing measures firmly in their place as being of marginal practical utility.

Women seem to be *over*-represented in motorcycle accidents compared with men. This is not an expected finding and not in accord with young car driver experience: it will be interesting to see if the female over-involvement is confirmed by the final analysis.

Helmet data collection normally takes up to six hours a helmet to extract the maximum amoung to potential information on injury impact point and level, type of damage, etc. There are some specific plans under way for systematically using this bank of helmet data. The helmet data recording forms used by USC are reported as Appendix 2 as an illustration of the series of USC forms developed for this NHTSA study. The Safety Helmet Council of America and the NHTSA are collaborating in collecting a large number of helmets to work out the probability distribution of impact levels and relate this to the impact levels for test qualification standards. This study was at that time expected to be under way by mid-1978.

The forms used by USC (See Appendix 2 for one of the series) are already in use in Swededn. Arn Luthander of the Royal Institute of Technology has already started to analyse data on this basis at the rate of 200 motorcycle accidents per annum, and is finding the forms appropriate for Swedish conditions. In view of this apparent compatibility between requirements, and the automatic consistency with the USC data set, there appears to be an priori case for suggesting that to the OECD Road Research Working Group S13 (which is presently in abeyance) that a wider use of such compatible coding for at least motorcycle analyses could be considered by further OECD member countries. The Transport Research Group of the Techniche Hochschule in Darmstardt is also currently considering such use of the USC forms. It would appear that the coordination of data on this difficult subject by the University of Southern California provides a material opportunity for Australian cooperation, if further work is to be undertaken here in the motorcycle safety field in this country, and this should be pursued at least to the stage of local field validation of the USC series of forms to identify potential shortfalls or advantages in local circumstances.

13. BELL HELMET COMPANY

13.1 ERNEST JEWELL: (VICE PRESIDENT, MANUFACTURING). NORWALK, CALIFORNIA.

We first discussed the general objectives of helmet standards activities within the U.S. Department of Transport, NHTSA. The general philosophy appears to be that the DOT Standard is set at a minimum acceptable standard. This applies to FMVSS 218 (on which AS 1698 is based and which is very close to Z90.1-1971 ANSI Standard) (Hearn *et al.*1978). On this classification, Z90.1-1978 is a "medium" standard and Snell 1975 is a "top" standard. Appropriate official contacts are:

(a) Dr. J.J. Liu (Georgia Tech., Michigan, Ph.D. in Biomechanics) U.S. DOT Office of Crash Worthiness who is now responsible for FMVSS 218.

(b) Mr. Armstrong U.S. DOT Office of Standards Enforcement.

(c) Mr. Clyde Rocquemore USA DOT ex-NHTSA and was responsible for FMVSS 218.

The Safety Helmet Council of America in their current meetings are seeking to obtain the removal of the dwell time requirements called up in FMVSS 218, and certainly to delete them from the current ANSI Z90.1 Standard. A formal letter from Dr. Snively as Chairman of the ANSI Z.90 Committee makes the grounds for this quite clear (Snively 1977). The Z90.1 Committee was formed at about the time of the completion of the Wayne State curve (Gurdjian *et al.* 1966) which was based on hairline skull fractures of cadavers. These results were instrumental in the recognition of dwell time as a legitimate factor in brain protection, but were totally inadequate to determine any specific values which might be used as part of a consistent helmet Standard. These events all occurred before the issue of Z90.1-1966 Standard.

The ANSI Z90.1 Committee has no specific policing duties or Government relationships. Dr. George Snively was in the chair in 1966 (Snively is the Research Director of the Snell Foundation), and at that time the formal procedure embodied in American Standard ANSI Z90.1 was to use a swingaway helmet 75"/2m.secs and 54"/4m.secs format. This was subsequently revised to a falling helmet test impacting a fixed anvil. Inearly 1970 U.S. DOT required a FMVSS for helmets, and added to the then-current issue of Z90.1 -1971 a centre of gravity requirement (within a 15° cone) and made the 2/4 millisecond dwell time a pass/fail requirement. This then was enacted on as law via FMVSS 218 in 1974. The centre of gravity requirement was of course suited to the medium sized "C" headform in use at the time, but the other sizes of headforms for FMVSS 218 were then referred to a contractor (responsible to Rocquemore) to produce the other sizes of headforms. The result has been the production of very heavy headforms in this attempt to meet the centre of gravity cone requirement with the larger and smaller headshapes (See Table 16). This could be considered to substantially compromise the whole purpose of the standard weight headform.

It should be further noted that the 2/4m.secs dwell times incorporated in the 200/150g levels of the Z90.1-1966 Standard were defined for swingaway helmet testing methods: in the change to fixed anvil testing procedures, the 2/4m.secs rating was accidentally taken over into Z90.1-1971, although it is known from Jehu (1971) that for equivalent impact performance the fixed anvil method produces *longer* dwell times as an artefact solely of the measurement technique itself (see Figure 20). The Standard was then changed to 3/6m.secs in 1972, (and taken over by the Australian Standards Association into AS 1698-1974), but the vast change in helmet performance then led to "failures" on dwell time in spite of vastly better impact attenuation. Consequently the ANSI Committee now wishes the data to be collected, but *NOT* to be used as a pass/fail issue until the new biomechanical data now becoming available has been reviewed to set an appropriate level.

TABLE 16

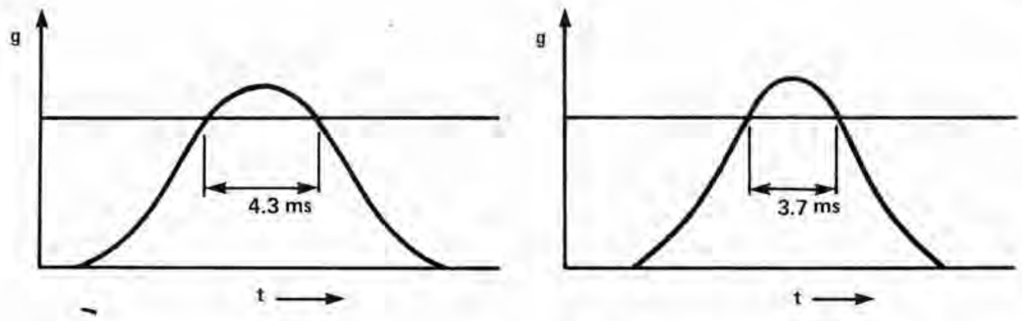
DROP ASSEMBLY WEIGHTS

HEADFORM SIZE	REQ. 218 WT.(LBS)	WT. BEFORE C.G. BALANCE (LBS)		WT. AFTER C.G. BALANCE (LBS)	
		DOT	SHCA	DOT	SHCA
A	7.8	9.141	9.194	9.839	9.756
B	8.9	9.804	9.824	10.278	10.272
C	11.0	11.312	11.294	14.726	14.708
D	13.4	12.954	12.954	15.256	16.367

(Source: Southwest Research Institute, 1977)

There has been a decline in the number of helmet manufacturers in the U.S.A. from around 45 in 1972/3 to a present total of around 18 in 1977/8. This has been due (at least in part to Product Liability legislation. Many helmet companies are "shell" companies which declare themselves bankrupt rather than face the first court case, once drawn. The defence of many such Product Liability cases has been good and well founded on experimental facts and data. Hurt (at University of Southern California) has often acted in the capacity of expert witness in injury reconstruction as a result of long standing in-depth accident study experience at his centre.

The Cragar Company manufactures magnesium headforms, and has always been closely associated with the Bell Helmet Company: it was the same man (Roy Richter) who started both. Richter has been strongly influenced by



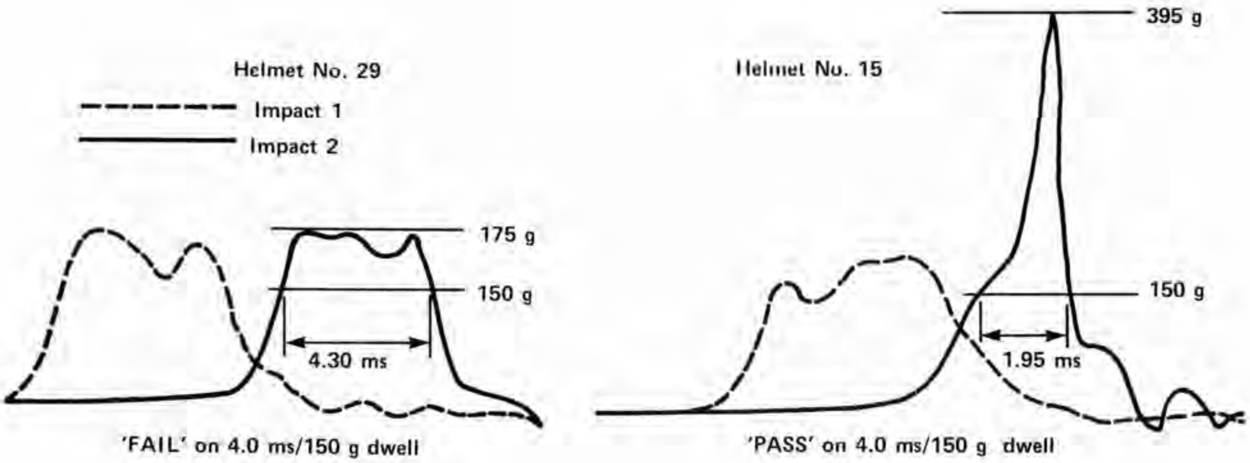
Test mode:	Rigid	Test mode:	Swingaway 0° arc setting
Impact energy:	98J (10m kgf)	Impact energy:	98J (10m kgf)
Calibration line:	334 g	Calibration line:	334 g
Peak deceleration:	411 g	Peak deceleration:	414 g
Time base:	10 sq/ms	Time base:	10 sq/ms

Rigid anvil 'dwell time' = 4.3 milliseconds

Swingaway 'dwell time' = 3.7 milliseconds

Fig 20 Time traces from rigid and swingaway test modes for blows of equal severity

Source (Jehu 1971)



'FAIL' on 4.0 ms/150 g dwell

'PASS' on 4.0 ms/150 g dwell

Source (Snively, 1977)

Fig 21

Using inappropriate pulse time criteria (4.0 msec. maximum at 150 G level), an excellent energy handling helmet 'fails', while a poor one 'passes'.

the work of George Snively and the Snell Foundation. FMVSS 218 is presently specified only for the "C" headform, i.e. for head sizes $7^1/_8$ to $7\frac{1}{2}$. No new research has yet been incorporated in FMVSS 218 since the ruling ANSI Draft Standard was enshrined in law as of 1974*. The four FMVSS 218 headforms were specified according to rough calculations as submitted to ANSI for Z90.1. Cragar then manufactured the four headforms according to this production practice (i.e. without the need for meeting centre gravity requirement). Southwest Research Institute was then commissioned to try to meet the 15° cone angle requirement imposed by FMVSS for sets of headform for SHCA** and U.S. DOT and have had some difficulties. It should also be noticed that the dwell time locked into FMVSS 218 forces the use of a fairly soft helmet liner, and in fact reduces the linear resistance reserve required to attenuate any higher impacts.

The U.S. Department of Transport has found it difficult to obtain a suitable supplier of headforms conforming to the 15° cone angle, the total weight, and the other requirements. Subsequent to the January meeting of the SHCA, Bell are now experimenting with the dropped anvil approach which obviously does not require a centre of gravity to be specified for the headform, and would therefore be suitable for use with all specified headforms. Subsequent to the Z90.1-1978 resolutions of the ANSI Z90.1 Committee in January 1978, the Committee is pressing for a new Standard. Only a very small minority still wishes to retain dwell time in this new Standard and Snively as Chairman has pressed on the Committee's behalf with the ANSI Board of Review for the removal of dwell time as a pass/fail test at 300 g's. Some of the reasons for this are illustrated by Figure 21 where the energy handling and dwell time performance of two helmets tested at Snell are shown to be at variance.

Experiments show that there are strong indications that the inclusion of dwell time requirements may assist "poor" (i.e. less impact reserve) helmets to pass and "good" (i.e. greater linear resistance reserve) ones to fail. This does however beg the question of what is defined to be "good". The U.S. Department of Transport recently canvassed the suitability of the "C" headform for testing helmets of all sizes. The SHCA Meeting did not agree on a response, but Bell finds that forcing small helmets onto a "C" headform gives 'bad' results, i.e. for sizes outside the $7^1/_8$ to $7\frac{1}{2}$ range a "C" headform produced spuriously good results using the specified test procedure. The universal use of a single headform would therefore provide an *easier* test for A, B, D helmets than for C. The dynamic and continuous review of Standards as set and reviewed by the Snell Foundation is exemplified by the willingness of Snell to deratify promptly if Standards slip. For example the Nava helmet was cited as having lost the Snell approval recently, but it could of course be reinstated as soon as the monitored performance rose again. It would clearly be advantageous to Australian users if a continuous review of helmets as actually offered at the point of sale were tested on a routine basis and the results published. Snell as a private foundation covers some of this task to a degree but the Snell Standard is not legally enforced in Australia, nor is continuous batch testing undertaken to provide continuous quality assurance as is the case for both U.K. and Australian Standards (Wigan 1978*a*). We were then taken on a tour of the Bell facilities. Numerous photographs were taken and are listed in Appendix 4 (See Figs. 22-25).

** Safety Helmet Council of America: present President is Ivan T. Wagar.

* This is now being corrected, coverage for other than 'C' headforms is in hand for FMVSS 218, and the ANSI Z90.1 Committee has now recommended a considerable increase in the drop height used for impact testing.

FIGURES 22-25 : PICTURES TAKEN AT BELL HELMET FACTORY, NORWALK, Ca

(See Appendix 4)

Visors are a subject of special concern in Australia. Bell uses acetate as the visor material although Lexan is better for scratching and impact resistance. Lexan loses its strength very easily on exposure to hydrocarbons of almost any variety. Acetate scratches very easily, although it is resistant to hydrocarbons. Bell is trying to improve the high scratchability of the acetate that they use at present. Jim Sandahl (Manager: Manufacturing Standards) referred to the VESC/8 visor impact standard. This is a simple drop test with some straightforward optical requirements. It is a minimal standard and a 1 mm thick acetate visor easily meets it. A number of difficulties with other material were raised: for example CR 39 has proved to be too brittle though good in other areas.

Helmet performance depends critically on fibreglass, resin, and liner materials. Bell is now using a special polystyrene which is extremely resistant to gasolene, and is also semi-resilient with about a 1 sec. hysteresis time. This semi-resilient high hysteresis material has been tested on the basis of velocity-in versus velocity-out in impact tests, but is likely to cause severe difficulties to in-depth accident study reporters after an accident! The acute resilience of polycarbonate shells is so high that the liner can get punctured and the shell show no visible sign of impact (See Figure 26 where the polycarbonate helmet shown has just failed a Snell 75 first drop test with these results. The peak headform acceleration recorded was 943g). Fibreglass helmets tend to show layer separation under such impacts, but the key signature is the depression or compression profiles produced in the crushable polystyrene types of lines.

A further technical development is a new resin which also has semi-resilient characteristics and has been recently proved in 16' drop tests at Bell. As an aside the question was raised of helmets built precisely to just meet specified Standards, as such a range of helmets had passed through the Bell Research Laboratory. It was confirmed to still be a real issue in a number of cases of products still offered for sale by some manufacturers. In view of the findings of both Hurt and Newman (1974) this may not be a problem of any great significance.

FIGURE 26: See appendix 4.

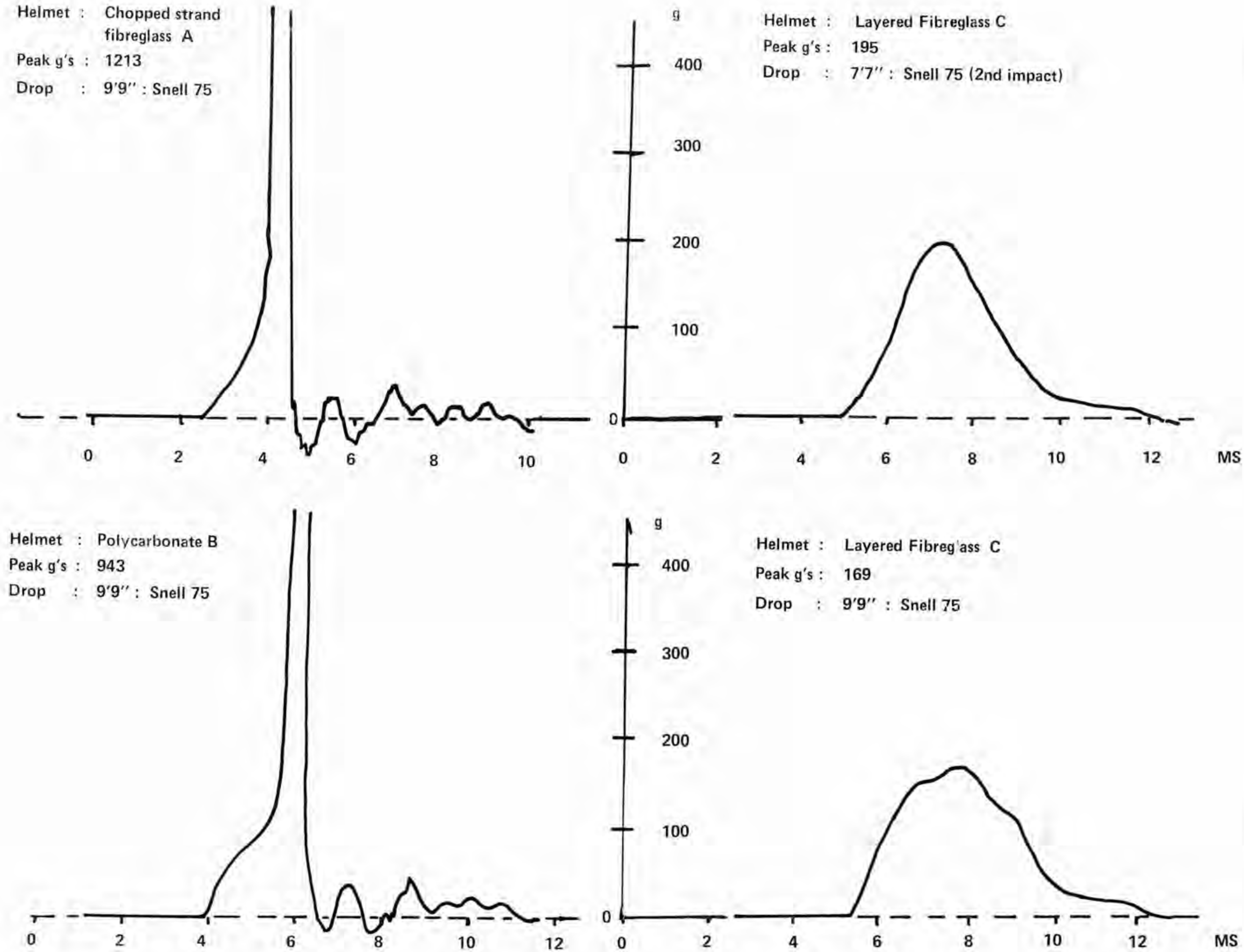


FIG.27: ACCELEROMETER TRACES IN THE BELL HELMET TESTING LABORATORY.

We were then taken to the test laboratory, where a number of helmets were put through Snell and other impact tests. Traces of accelerometer results for a chopped fibreglass and a polycarbonate helmet were then produced from the tests we watched being carried out. Some of the findings are quite disconcerting when the severe impact standard specified by Snell 75 is used in place of FMVSS 218 drop heights. Figure 27 shows some of these accelerometer traces.

Bell Helmets make a point of trying to retrieve helmets after accidents, and a number of distributors have a policy of substantial credits for the return of damaged helmets. This is not unique to Bell (e.g. the Life Helmet Company in the U.K. provides a lifetime replacement guarantee for accident damage and the Australian Haritos Company is also moving towards similar arrangements, to provide an example of the range of such arrangements in these countries). The quality of the helmet data set being collated as part of the major NHTSA in-depth accident study on motorcycles being carried out by Hurt at USC benefits from this approach, as new helmets were offered for those used by people involved in accidents even if the helmet had not been visibly damaged. This led to the accumulation of the enormous collection of helmets involved in accidents now available at USC for further study. Again this is not a unique manufacturer response, and the study is actively supported by the Safety Helmet Council of America as a whole (Hurt and Dupont, 1977).

14. SUMMARY

This is not a visit report in the normal form. Although the material was drawn from a number of meetings held over a period of a week, it seemed more appropriate to use it selectively to provide a more material review of the subjects raised. Associated documents have also been collated and integrated into the reference list. It is hoped that the report now provides a reasonably well supported review of the safety issues covered in discussions. The subject matter is not readily available in a collated form, and it has repeatedly been put to the author that the reorganisation of this and other material - supported by a consistent level of basic information - into a substantial reference document would be of wide interest and practical value.

It is evident that in the areas of driver testing and training, braking, Design Rules, user profiles, vehicle usage, accident incidence, protective clothing, mopeds, and vehicle stability there is now a sufficient level of research results to permit coherent and systematic regulatory and usage policies to be developed for powered two wheelers. It is also clear that the limited depth and coverage of the present review needs to be improved on by a series of sectoral reviews as so much of the material has yet to be digested into a suitable form for such committees as those of ATAC, the Standards Association and other bodies concerned with motorcycles and mopeds. Initial work to this end has been initiated (Wigan 1978*a*, *b*, 1979*a*; Wigan and Thoresen 1979).

Report written by:

Ramsay Wigan

Report reviewed by:

[signature]

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APPENDIX 1: NHTSA VEHICLE ENGINEERING ORGANISATION wef 1 1 78

Vehicle Engineering Research Division
NRD-12
Forthofer, Robert J.
— Sec

- **Automotive Systems Research Branch** — Stahler, Norman
  - Lourenco Manuel
  - Williams, Sidney
  - Grieder, Dennis
  - Klaber, Keith
  - Emery, Lloyd
  - Wu, Yung-Kuang
- **Structures Branch** — Hackney, James
  - Bell, Gary
  - Hollowell, William
  - Abney, Timothy
  - Ragland, Carl
  - Pierce, Steve
- **Occupant Packaging Branch** — Morris, John
  - Morgan, Richard
  - Clark, Carl
  - Bliss, David
- **Biomechanics Branch** — Hirsch, Arthur
  - Eppinger, Rolf
  - Johnson, Arnold
  - Ovenshire, Lee
  - Chan, Han-Sun
  - Pickering, Ray

INTEGRATED VEHICLE RESEARCH DIVISION NRD-11
William Boehly, Division Chief

- **VEHICLE DEVELOPMENT BRANCH**
  - Edward Chandler, Chief
  - Arthur Henry
  - Jerome Kossar
  - Frank Richardson
- **TECHNOLOGY TRANSFER BRANCH**
  - Francis Dilorenzo, Chief
  - Charles Daye
  - Joseph Kanianthra

Located at: Transpoint Building
2100 SW 2nd Street. Washington DC, USA.

APPENDIX 2:

HELMET

1. USC ACCIDENT #:

2. HELMET INFORMATION FOR:
1) Rider 2) Passenger

3. HELMET MANUFACTURER: (SEE LISTING)
(Model, if known)________
98) Not observed 99) N/A

4. HELMET DATE OF MANUFACTURE: MONTH YEAR
98) Not observed 99) N/A

5. DOT FMVSS-218 QUALIFICATION LABEL:
1) Yes 2) No 3) No. U.S. DOT disclaimer label attached 8) Not observed
9) N/A

6. ANSI Z-90 standard labeled:
1) Yes, 1966 2) Yes, 1971 3) No 8) Not observed 9) N/A

7. SHCA certified:
SHCA Certification No.:________ 1) Yes 2) No 8) Not observed
9) N/A

8. SHELL QUALIFICATION: SERIAL #________
1) Yes, 1962 2) Yes, 1969 3) Yes, 1970
4) Yes, 1975 5) No 8) Not observed 9) N/A

9. HELMET WEIGHT: ACTUAL WEIGHT LBS.________
1) Less than 1.75 lbs. 2) 1.75 to 1.99 lbs. 3) 2.00 to 2.24 lbs.
4) 2.25 to 2.49 lbs. 5) 2.50 to 2.74 lbs. 6) 2.75 to 2.99 lbs
7) 3.00 to 3.24 lbs. 8) 3.25 lbs and over. 98) Unknown 99) N/A.

10. TYPE OF COVERAGE:
1) Partial 2) Full 3) Full facial 105° 4) Full facial 120°
8) Not observed 9) N/A

11. CONDITION OF HELMET PRIOR TO TRAFFIC ACCIDENT:
1) Damaged (describe)________
2) Not damaged 8) Not observed 9) N/A

12. WAS RETENTION SYSTEM FASTENED PRIOR TO TRAFFIC ACCIDENT:
1) Yes 2) No 8) Not observed 9) N/A

13. DID HELMET REMAIN ON HEAD DURING CRASH IMPACT AND/OR FALL:
1) Yes 2) No 8) Not observed 9) N/A

14. TYPE RETENTION SYSTEM:
0) None 1) D-rings 2) Snaps 3) Snaps & D-rings 4) Quick release
5) Other 8) Not observed 9) N/A

15. IF RETENTION SYSTEM FAILED, WHAT KIND OF FAILURE:
1) Pulled through D-rings 2) Quick release let go 3) Unsnapped
4) Broke rivet 5) Webbing failure 6) Shell failure at rivet hole
7) Other________ 8) Not observed/unknown 9) N/A, no failure

16. HELMET FIT:
1) Small - too tight 2) Approximately correct 3) Large - too big
4) Extremely loose 5) Poor contour match 8) Not observed 9) N/A

17. ETHNICITY:
1) Negroid 2) Caucasoid 3) Oriental 4) Mexican-American
5) American-Indian 6) Other________ 8) Not observed/unknown

SAMPLE SEGMENT OF USC IN DEPTH ACCIDENT REPORTING FORMS

18. SHELL MATERIAL: . . . . ☐

1) Fiberglass 2) Polycarbonate 3) Other (specify)________________
8) Not observed 9) N/A

19. MEASURED DENSITY OF FOAM LINER OR CROWN __________LBS./FT^3: . . . . . . ☐☐
98) Not observed 99) N/A

20. THICKNESS OF LINER AT POINT SYMMETRICAL TO IMPACT (IN.): . . . . . . ☐.☐
98) Not observed 99) N/A

21. LINER MATERIAL AT POINT OF IMPACT: . . . . ☐

0) None, including comfort or fitting pad 1) Styrofoam (EPS) Large bead
2) Styrofoam (EPS) small bead 3) Polyurethane 4) Ethafoam
5) Neoprene sponge 6) Polypropylene 7) Other 8) Not observed 9) N/A

22. MAXIMUM AMOUNT OF CRUSH AT P.O.I. (IN) . . . . ☐.☐
98) Not observed 99) N/A

23. AREA OF CRUSH OR SIGNATURE: (IN^2). . . . . ☐☐.☐☐
9998) Not observed 9999) N/A

24. LENGTH OF TIME AFTER IMPACT TO CRUSH ANALYSIS: . . . . ☐☐ HOURS
98) Not observed 99) N/A

25. NORMAL COMPONENT OF IMPACT VELOCITY . . . . ☐☐ M.P.H.
98) Not observed 99) N/A

26. TYPE OF IMPACT: . . . . ☐

1) Essentially normal 2) Essentially tangential 3) Crushing
8) Unknown, not observed 9) N/A

27. NUMBER OF IMPACTS AT THIS SITE: . . . . ☐
8) Not observed 9) N/A

28. MOST SERIOUS TYPE OF DAMAGE TO SHELL . . . . ☐☐

0) No damage 1) Abrasion 2) Puncture 3) Crack, split, shatter
4) Resin fracture 5) Delamination 6) Crazing from residual stress
7) Internal damage only 8) Fire 9) Multiple________ 10) Other_______
98) Not observed 99) N/A

29. LOCATION OF DAMAGE TO SHELL: (SEE DIAGRAMS) . . . . ☐☐ ☐☐ TOP SIDE
____ ____(top) x ____ ____(side) 8) Not observed 9) N/A

30. GEOMETRY OF STRUCK OBJECT: . . . . ☐

1) Flat 2) Blunt edge 3) Sharp edge 4) Blunt object 5) Sharp object
8) Not observed 9) N/A

31. MATERIAL OF OBJECT STRUCK: . . . . ☐

1) Metal 2) Glass 3) Wood 4) Soil 5) Pavement 6) Other__________
8) Not observed 9) N/A

SECOND IMPACT (QUESTIONS 32-41)

32. THICKNESS OF LINER AT POINT SYMMETRICAL TO IMPACT (IN.): . . . . . . ☐.☐☐
98) Not observed 99) N/A

33. LINER MATERIAL AT POINT OF IMPACT: . . . . ☐

0) None, including comfort or fitting pad 1) Styrofoam (EPS) large bead
2) Styrofoam (EPS) small bead 3) Polyurethane 4) Ethafoam
5) Neoprene sponge 6) Polypropylene 7) Other 8) Not observed 9) N/A

34. MAXIMUM AMOUNT OF CRUSH AT P.O.I. (IN IN.): . . . . ☐.☐
98) Not observed 99) N/A

35. AREA OF CRUSH OR SIGNATURE: (IN^2). . . . . ☐☐.☐☐
9998) Not observed 9999) N/A

36. LENGTH OF TIME AFTER IMPACT TO CRUSH ANALYSIS: (HOURS) . . . . [ ][ ]
98) Not observed 99) N/A

37. NORMAL COMPONENT OF IMPACT VELOCITY . . . . [ ][ ] M.P.H.
98) Not observed 99) N/A

38. TYPE OF IMPACT: . . . . [ ]
1) Essentially normal 2) Essentially tangential 3) Crushing
8) Unknown, not observed 9) N/A

39. NUMBER OF IMPACTS AT THIS SITE: . . . . [ ]
8) Not observed 9) N/A

40. MOST SERIOUS TYPE OF DAMAGE TO SHELL . . . . [ ][ ]
0) No damage 1) Abrasion 2) Puncture 3) Crack, split, shatter
4) Resin fracture 5) Delamination 6) Crazing from residual stress
7) Internal damage only 8) Fire 9) Multiple________ 10) Other______
98) Not observed 99) N/A

41. LOCATION OF DAMAGE TO SHELL: (SEE DIAGRAMS): . . . . [ ][ ] TOP [ ][ ] SIDE
____ ____(top) x ____ ____(side) 98) Not observed 99) N/A

42. PREDOMINATING COLOR OF HELMET: . . . . [ ][ ]
1) White 2) Yellow 3) Orange 4) Black 5) Brown 6) Blue 7) Red
8) Purple 9) Green 10) Silver 11) Grey 12) Gold 13) Chrome/Metal Flake
14) Other____________ 98) Not observed, unknown 99) N/A

43. ANY EYE AND FACE PROTECTION (EXCLUDING GLASSES AND CONTACTS) USED AT TIME OF TRAFFIC ACCIDENT: . . . . [ ]
0) None 1) Goggles 2) Wrap around face shield 3) Bubble type face shield
4) Visor and face shield combination 5) Other (specify)________________
8) Not observed, unknown

44. COLOR OF EYE PROTECTORS: . . . . [ ]
1) Clear 2) Green 3) Amber 4) Smoke 5) Blue 6) Other (specify)______
8) Not observed 9) N/A

45. WAS MOTORCYCLE RIDER WEARING: . . . . [ ]
0) None of the following 1) Prescription glasses 2) Contacts
3) Prescription sunglasses 4) Contacts and sunglasses 8) Not observed
5) Non-prescription sunglasses 6) Non-prescription clear glasses

46. WAS ANY FAILURE TO DETECT TRAFFIC HAZARD RELATED TO HEAD, FACE, OR EYE PROTECTION: . . . . [ ]
0) None 1) Helmet attenuated critical traffic sounds 2) Helmet limited vision
3) Helmet caused fatigue 4) Eye protection faulty, unclear or distorted vision
5) Eye protection framework limited or obstructed vision 6) 1 and 2
7) 2 and 4 8) Unknown, not observed 9) N/A

47. TYPE OF ACCIDENT-INDUCED DAMAGE TO FACE SHIELD: . . . . [ ]
0) None 1) Abrasion 2) Puncture 3) Crack 4) Shatter 5) Other (specify)
8) Not observed 9) N/A ____________

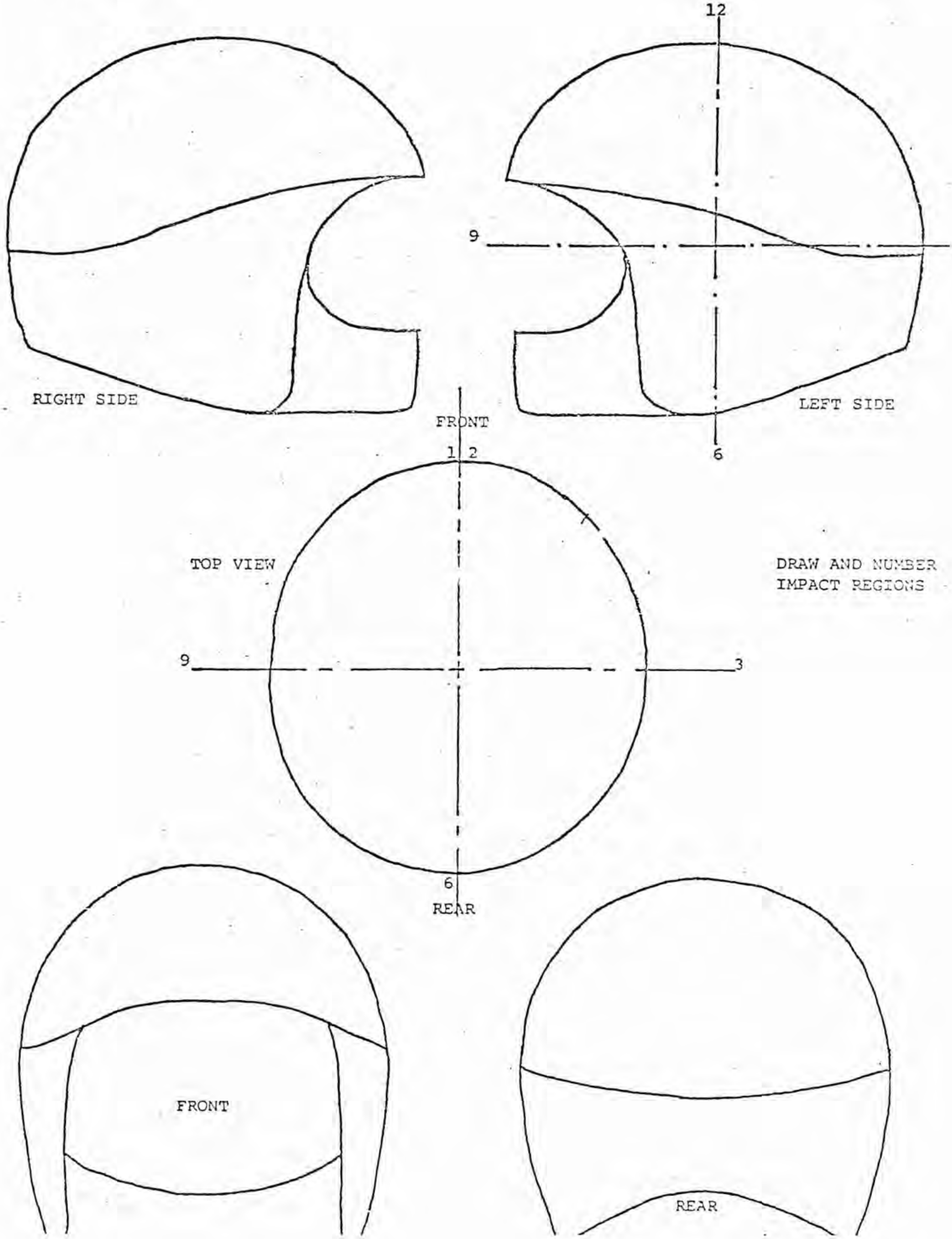
48. LOCATION OF ACCIDENT-INDUCED DAMAGE TO FACE SHIELD: . . . . [ ]
1) Center 2) Upper right 3) Upper left 4) Lower right 5) Lower left
8) Not observed 9) N/A

49. CRASH INJURIES ATTRIBUTABLE TO EYE PROTECTION: . . . . [ ]
0) None 1) Yes (describe)__________________________ 8) Not observed
9) N/A

50. FREQUENCY OF HELMET USE: . . . . [ ][ ][ ]
__________% of time 0) Never 998) Not observed

51. CONDITIONS UNDER WHICH HELMET IS USUALLY WORN: . . . . [ ]
0) Never 1) Surface roads 2) Highway and freeway use 3) Always
4) Other (specify)______________ 8) Not observed

52. HELMET RELATION TO INJURIES: . . . . [ ]
0) None 1) Prevented injury 2) Attenuated injury 3) Caused or aggravated
4) Attenuated or prevented one injury but caused or aggravated another injury 5) Other________ 8) Unknown 9) N/A


12
9
RIGHT SIDE
LEFT SIDE
6
FRONT
1 2
TOP VIEW
DRAW AND NUMBER
IMPACT REGIONS
9
3
6
REAR
FRONT
REAR

PASSENGER SUPPLEMENT
(Revision 29/6/76)

1. U S C Accident No. . . . . [ ]

2. Passenger #: 1 2

3. SEX: . . . . [ ]
1) Male 2) Female 3) Not observed

4. HEIGHT: . . . . [ ]
______ inches 98) Not observed

5. WEIGHT: . . . . [ ]
______ lbs. 998) Not observed

6. OCCUPATIONAL CODE OF OPERATOR: . . . . [ ]
1) Professional, technical 2) Manager, administrator (except farm) 3) Sales workers
4) Clerical, kindred 5) Craftsman, kindred 6) Operatives (except transport)
7) Transport equipment operatives (drivers) 8) Laborers (except farm)
9) Farmers, farm managers 10) Farm laborers, foreman 11) Service worker (except below)
12) Private household worker 13) Housewife 14) Student 15) Military
16) Retired 17) Unemployed (over 1 month) 98) Unknown

7. PASSENGER RIDE ON MOTORCYCLES OFTEN: . . . . [ ]
0) Never before 1) Seldom 2) Occasionally 3) Often 4) Very often
8) Not observed

8. ALCOHOL AND/OR DRUG IMPAIRMENT: . . . . [ ]
1) Had been drinking, not under influence 2) Had been drinking, under influence
3) Had been drinking, impairment unknown 4) Under drug influence 5) Combination
6) Other impairment__________ 8) Unknown 9) N/A

9. BLOOD ALCOHOL LEVEL CORRECTED TO TIME OF ACCIDENT INVOLVEMENT: . . . . . [ ]
00) No alcohol in blood 01-96) Hundredths of 1% of blood alcohol
97) Blood alcohol higher than .96% 98) Blood alcohol level not observed

10. USE OF DRUGS OTHER THAN ALCOHOL: . . . . [ ] A B
A. 0) None 1) Prescription 2) Non-prescription 8) Not observed/unknown
B. 0) None 1) Marijuana 2) Stimulants 3) Depressants 4) Psychedelics
5) Antihistamines, depressant 5) Antihistamines, stimulant
7) Multiple (including alcohol)__________ 8) Not observed/unknown

11. PASSENGER POSITION ON MOTORCYCLE AT TIME OF IMPACT: . . . . [ ]
1) Normal seated position 2) Standing on footrests, foot pegs 3) Head down
4) Shoulder check left 5) Shoulder check right 6) Dismounting, bailing out
7) Other__________ 8) Not observed 9) N/A

12. UPPER TORSO COVERAGE: . . . . [ ]
0) None 1) Light cloth 2) Medium cloth 3) Heavy cloth or naugahyde 4) Leather
8) Not observed

13. DID COVERAGE PREVENT OR REDUCE INJURY: . . . . [ ]
1) Yes 2) No 8) Not observed 9) N/A 0) No contact in area

13.1. LOWER TORSO COVERAGE: . . . . [ ]
0) None 1) Light cloth 2) Medium cloth 3) Heavy cloth or naugahyde 4) Leather
8) Not observed

15. DID COVERAGE PREVENT OR REDUCE INJURY: . . . . [ ]
1) Yes 2) No 8) Not observed 9) N/A 0) No contact in area

16. FOOT COVERAGE: . . . . [ ]
0) None 1) Light sandal, loafer 2) Medium, street shoe 3) Heavy shoe or boot
8) Not observed

17. DID COVERAGE PREVENT OR REDUCE INJURY: . . . . [ ]
1) Yes 2) No 8) Not observed 9) N/A 0) No contact in area

18. GLOVES: . . . . [ ]
0) None 1) Light 2) Medium 3) Heavy 8) Not observed

19. DID COVERAGE PREVENT OR REDUCE INJURY: . . . . [ ]
1) Yes 2) No 8) Not observed 9) N/A 0 No contact in area

20. HELMET WORN: . . . . [ ]
1) Yes, helmet acquired for examination (fill out helmet supplement)
2) Yes, helmet not acquired for examination 3) No 8) Not observed

21. REASONS FOR NOT WEARING HELMET: . . . . [ ]
1) Inconvenient and/or uncomfortable 2) Cost excessive 3) Reduced awareness of traffic
4) No expectation of accident involvement 5) Owns helmet, not accessible or in possession at time of accident
6) Wary helmet-induced injuries
7) Other__________ 8) Not observed 9) N/A

22. ON-SCENE MEDICAL ASSISTANCE: . . . . [ ]
0) None 1) Private ambulance 2) Public ambulance 3) M.D. 4) Coroner
5) Private party 6) Law enforcement 7) Other (specify) 8) Not observed

23. RESCUE AMBULANCE NUMBER: ______________

24. (TYPE OF EMERGENCY MEDICAL TREATMENT ADMINISTERED TO PASSENGER: 0) None 1) Yes
8) Not observed)

25. HEMORRHAGE CONTROL: . . . . [ ]

26. SPLINTING OF LIMBS (BACK BOARDS): . . . . [ ]

27. RESUSCITATION: . . . . [ ]

28. I.V. - INJECTIONS: . . . . [ ]

29. CARDIO-VASCULAR RX: . . . . [ ]

30. RX OF HEAD WOUNDS: . . . . [ ]

31. OTHER (SPECIFY): ______________

32. STATUS OF TRAUMATIC INJURIES: . . . . [ ]
1) First aid at scene 2) Treated at hospital/clinic and released
3) Hospitalized for less than 24 hours 4) Hospitalized for significant Rx
5) Anticipated outpatient care only 6) Fatal - dead on scene 7) Fatal - DOA
8) Fatal - dead within 24 hours 9) Fatal - dead period unknown 98) Not observed 99) N/A

33. HOSPITAL TAKEN TO: ______________

34. BODY TATTOOS: . . . . [ ]
0-6) Number of tattoos 7) More than 6 8) Unknown

Date of birth ______________

HEAD/NECK INJURY QUESTIONNAIRE

ENTER CODE(S) FOR AREA(S) OF POSSIBLE CONTACT (SEE APPENDICES E & F) (Alphanumeric, 4 each)

HEAD/NECK REGION *
SIDE *
ASPECT *
LESION *
SYSTEM/ORGAN *
SEVERITY @

REGION *
SIDE *
ASPECT *
LESION *
SYSTEM/ORGAN *
SEVERITY @

RELATED INJURIES NOT AT CONTACT SITE

REGION *
SIDE *
ASPECT *
LESION *
SYSTEM/ORGAN *
SEVERITY @

(keypunch by columns, left to right)

* See Appendix K
@ See Appendix J

SOMATIC INJURY QUESTIONNAIRE

ENTER CODE(S) FOR AREA(S) OF POSSIBLE CONTACT (SEE APPENDICES E & F) (Alphanumeric, 4 each)

1. __________
2. __________
3. __________
4. __________

BODY REGION *
SIDE *
ASPECT *
LESION *
SYSTEM/ORGAN *
SEVERITY @

REGION *
SIDE *
ASPECT *
LESION *
SYSTEM/ORGAN *
SEVERITY @

RELATED INJURIES NOT AT CONTACT SITE

REGION *
SIDE *
ASPECT *
LESION *
SYSTEM/ORGAN *
SEVERITY @

(keypunch by columns, left to right)

* See Appendix I
@ See Appendix J

AR — Motorized Bicycle: Every bicycle with fully operative pedals for propulsion by human power, and automatic transmission, and a motor with a cylinder capacity not exceeding fifty (50) cubic centimeters, which provides no more than two point zero (2.0) brake horsepower, and is capable of propelling the bicycle at a maximum design speed of no more than thirty (30) miles per hour on level ground.

(Act 561, 1977 Laws)

AZ — Pedal Bicycle with Helper Motor: Every bicycle equipped with a helper motor, if such vehicle has a maximum piston displacement of fifty (50) cubic centimeters or less, a brake horsepower of one and one-half or less, and a maximum speed of twenty-five (25) miles per hour or less on a flat surface with less than one per cent grade.

(Chapter 78, 1976 Laws)

CA — Motorized Bicycle: Any two-wheeled or three-wheeled device having fully operative pedals for propulsion by human power, or having no pedals if powered solely by electrical energy, and an automatic transmission and a motor which produces less than 2 gross brake horsepower and is capable of propelling the device at a speed of not more than 30 miles per hour on level ground.

(Chapter 987, 1975 Laws)

CO — Motorized Bicycle: A vehicle having two or three wheels with operable pedals which may be propelled by human power or helper motor, or both, with a motor rated no more than two-brake horsepower, a cylinder capacity not exceeding 50 c.c., and an automatic transmission which produces a maximum design speed of not more than thirty miles per hour on flat surface.

(SB 69, 1977 Laws)

CT — Bicycle: Includes all vehicles propelled by the person riding the same by foot or hand power or a helper motor having a capacity of less than fifty cubic centimeters piston displacement and rated not more than two brake horsepower and capable of a maximum speed of no more than thirty miles per hour and equipped with automatic transmission and operable pedals.

(Public Act 76-250, 1976 Laws)

DC — Motorized Bicycle: Any motor vehicle having either a tandem arrangement of two wheels equipped with tires which are sixteen or more inches in diameter or a tricyclic arrangement of three wheels equipped with tires which are sixteen or more inches in diameter, having a seat or saddle for the use of the operator, weighing not more than 120 pounds, having an automatic transmission, and having a motor or engine which produces not more than 1.5 brake horsepower (S.A.E. rating), has a piston displacement of not more than 50 cubic centimeters, and is capable of moving the vehicle at a maximum speed of not more than 25 miles per hour on level ground when propelled exclusively by such motor or engine.

(Law 1-110, 1977 Laws)

DE — Moped: A pedal bicycle having two tandem wheels, either of which is over twenty inches in diameter, and having a helper motor, characterized in that the maximum piston displacement is less than 55cc., rated at no more than 1.5 brake horsepower, and that the maximum speed does not exceed 25 miles per hour.

(Chapter 63, 1977 Laws)

FL — Bicycle: Any device propelled by human power, or any "moped" propelled by a pedal activated helper motor with manufacturer's certified maximum rating of 1½ brake horsepower, upon which any person may ride, having 2 tandem wheels either of which is 20 inches or more in diameter, and including any device generally recognized as a bicycle though equipped with 2 front or 2 rear wheels.

(HB 328, 1976 Laws)

HI — Bicycle: Every device propelled by human power or motor power of one and one-half horsepower or less upon which any person may ride, having two tandem wheels sixteen inches in diameter or greater, and including any device generally recognized as a bicycle though equipped with two front or two rear wheels.

(Act 148, 1976 Laws)

IA — Motorized bicycle or motor bicycle: A two-wheeled motor vehicle with an engine having a displacement no greater than fifty cubic centimeters as fixed by the department and not capable of operation at a speed in excess of twenty-five miles per hour on level ground unassisted by human power.

(HF 1332, 1976 Laws)

IL — Motorized Pedalcycle: A bicycle type vehicle, which has tires with an overall inflated diameter of 19 inches or more, with fully operative pedals for propulsion by human power, equipped with a power drive system that functions directly or automatically only and not requiring clutching or shifting by the operator after the drive system is engaged, and a helper motor with a cylinder capacity not exceeding 50 cubic centimeter displacement, which produces no more than 2.0 brake horsepower, and is capable of propelling the vehicle at a maximum speed of no more than 30 m.p.h. on level ground.

(Public Act 80-262, 1977 Laws)

IN	Motorized Bicycle: A bicycle with operable pedals which may be propelled by human power or by an internal combustion engine or a battery powered motor, or by both, and when powered by an internal combustion engine having a rating of no more than one and five-tenths (1.5) brake horse-power and a cylinder capacity not exceeding fifty (50) cubic centimeters, an automatic transmission, and a maximum design speed of no more than twenty-five (25) miles per hour on a flat surface. (HB 1481, 1977 Laws)
KS	Motorized Bicycle: Every device having two (2) tandem wheels which may be propelled by either human power or helper motor, or by both, and which has: A motor which produces not more than one and one-half (1½) brake horsepower; a cylinder capacity of not more than fifty (50) cubic centimeters; an automatic transmission; and the capability of a maximum design speed of no more than twenty-five (25) miles per hour. (HB 2095, 1977 Laws)
LA	Motorized Bicycle: A pedal bicycle which may be propelled by human power or helper motor, or by both, with a motor rated no more than one and one-half brake horsepower, a cylinder capacity not exceeding fifty cubic centimeters, an automatic transmission, and which produces a maximum design speed of no more than twenty-five miles per hour on a flat surface. (Act 192, 1976 Laws)
MA	Motorized Bicycle: A pedal bicycle which has a helper motor rated no more than 1.5 brake horsepower, a cylinder capacity not exceeding fifty cubic centimeters, an automatic transmission, and which is capable of a maximum design speed of no more than twenty-five miles per hour. (Chapter 261, 1976 Laws)
MD	Bicycle: A vehicle that is designed to be operated by human power or with assistance of a motor that has a capacity of less than 50 cubic centimeters piston displacement or rated less than one brake horsepower, that has two or three wheels of which one is more than 14 inches in diameter, that have a rear drive, and with wheel configuration as follows: (1) Two wheels - In tandem (2) Three wheels - Single front wheel with two rear wheels on a horizontal axis perpendicular to the longitudinal plane of the front wheel and spaced equidistant from the front wheel centerline. (Chapter 406, 1976 Laws)
ME	Moped: A motor driven cycle with 2 or 3 wheels that may have foot pedals to permit muscular propulsion, and has a power source to provide up to a maximum of 2 brake horsepower, a motor with a cylinder capacity not exceeding 50 cubic centimeters which will propel the vehicle unassisted at a speed not to exceed 30 miles per hour on a level road surface, and is equipped with a power drive system that functions directly or automatically only and which does not require clutching or shifting by the operator after the drive system is engaged. (Chapter 402, 1977 Public Laws)
MI	Moped: A 2- or 3-wheeled vehicle with operable pedals which is equipped with a motor that does not exceed 50 cubic centimeters piston displacement, produces 1.5 brake horsepower or less, and cannot propel the vehicle at a speed greater than 25 miles per hour on a level surface. (Public Act 54, 1977 Laws)
MN	Motorized Bicycle: A bicycle with fully operable pedals which may be propelled by human power or a motor, or by both, with a motor of a capacity of less than 50 cubic centimeters piston displacement, and a maximum of two brake horsepower, which is capable of a maximum speed of not more than 30 miles per hour on a flat surface with not more than one percent grade in any direction when the motor is engaged. (Chapter 214, 1977 Laws)
NC	Bicycle with Helper Motor: A bicycle with a helper motor that is rated at less than one brake horsepower, and produces only ordinary pedaling speeds up to a maximum of 20 miles per hour. (Chapters 94 & 859, 1975 Laws)
NH	Moped: Any two-wheeled or three-wheeled pedal vehicle with an automatic transmission and a helper motor, internal combustion or electric, which is rated at no more than 2 brake horsepower, has a cylinder capacity not exceeding 50 cubic centimeters and has a maximum design speed of less than 30 miles per hour on level ground. (Chapter 272, 1977 Laws and Chapter 4, 1976 Laws)
NJ	Motorized Bicycle: A pedal bicycle having a helper motor characterized in that either the maximum piston displacement is less than 50 cc. or said motor is rated at no more than 1.5 brake horsepower and said bicycle is capable of a maximum speed of no more than 25 miles per hour on a flat surface. (Chapter 267, 1977 Laws)
NM	Motorized Bicycle: A two-wheeled or three-wheeled device having fully operative pedals for propulsion by human power, an automatic transmission and a motor having a piston displacement of less than fifty cubic centimeters, which is capable of propelling the device at a maximum speed of not more than twenty-five miles per hour on level ground. (Chapter 135, 1977 Laws)
NV	Moped: A vehicle which looks and handles essentially like a bicycle and can be propelled either by pedaling or by a small engine and: (1) is designed to travel on not more than three wheels in contact with the ground but is not more than three wheels in contact with the ground but is not a tractor; and (2) is capable of a maximum speed of not more than 1 percent grade in any direction when the motor is engaged. (SB 174, 1975 Laws)

NY Limited Use Motorcycle: An unenclosed limited use vehicle having only two or three wheels, with a seat or saddle for the operator. A limited use motorcycle having a maximum performance speed of more than thirty miles per hour but not more than forty miles per hour shall be a class A limited use motorcycle. A limited use motorcycle having a maximum performance speed or more than twenty miles per hour but not more than thirty miles per hour shall be a class B limited use motorcycle. A limited use motorcycle having a maximum performance speed of not more than twenty miles per hour shall be a class C limited use motorcycle.

(Chapter 931, 1977 Laws)

*pedestrian injury liability only.

OH Motorized Bicycle: Any vehicle having either two tandem wheels, or one wheel in the front and two wheels in the rear, that is capable of being pedaled and is equipped with a helper motor of not more than fifty cubic centimeters piston displacement which produces no more than one brake horsepower and is capable of propelling the vehicle at a speed of no greater than twenty miles per hour on a level surface.

(SB 100, 1977 Laws).

PA Motorized Pedalcycle: A motor-driven cycle equipped with operable pedals, a motor rated no more than 1.5 brake horsepower, a cylinder capacity not exceeding 50 cubic centimeters, an automatic transmission, and a maximum design speed of no more than 25 miles per hour.

(Act 81, 1976 Laws)

RI Motorized Bicycle: Pedal bicycle which may be propelled by human power or helper motor, or by both, with a motor rated no more than 1.5 brake horsepower which is capable of a maximum speed of not more than twenty-five (25) miles per hour.

(Chapter 64, 1976 Laws)

SC Bicycle: Every device propelled by human power upon which any person may ride, having two tandem wheels, and including pedal bicycles with helper motors rated less than one brake horsepower which produce only ordinary pedaling speeds up to a maximum of twenty miles per hour.

(HB 2042, Ratification No. 258, 1977 Laws)

TN Motorized Bicycle: A vehicle with fully operable pedals for propulsion by human power, an automatic transmission, and a motor with a cylinder capacity not exceeding fifty cubic centimeters (50cc) which produces no more than one and one half (1.5) brake horsepower and is capable of propelling the vehicle at a maximum design speed of no more than twenty-five miles per hour (25mph) on level ground.

(Chapter 428, 1977 Public Laws)

TX Motor-assisted Bicycle: A bicycle which may be propelled by human power or a motor, or by both, with a motor of a capacity of less than sixty (60) cubic centimeters piston displacement, which is capable of a maximum speed of not more than twenty (20) miles per hour on a flat surface with not more than one (1) percent grade in any direction when the motor is engaged.

(HB 1196, 1973 Laws)

VA Bicycle: "Bicycle" shall include pedal bicycles with helper motors rated less than one brake horsepower which produce only ordinary pedalling speeds up to a maximum of twenty miles per hour, provided such bicycles so equipped shall not be operated upon any highway or public vehicular area of this State by any person under the age of sixteen years.

(SB 811, 1975 Laws)

VT Moped: A motor driven cycle equipped with two or three wheels, foot pedals to permit muscular propulsion, a power source providing up to a maximum of two brake horsepower and having a maximum piston or rotor displacement of 50 cubic centimeters if a combustion engine is used, which will propel the vehicle, unassisted, at a speed not to exceed 30 miles per hour on a level road surface and is equipped with a power drive system that functions directly or automatically only, not requiring clutching or shifting by the operator after the drive system is engaged.

(Act 20, 1977 Laws)

APPENDIX 4:

LIST OF PHOTOGRAPHS TAKEN AT BELL HELMET FACTORY, NORWALK Ca AND AT CALIFORNIA DEPARTMENT OF MOTOR VEHICLES MOTORCYCLE LICENCING TEST SITE IN SACRAMENTO

ARRB Ref. No.	Figure No. in this Report	Description
36		Planetary headform for checking
37		Drilled helmet shells used for liner match control and checking.
		Examples of acceptable and unacceptable liner formation: quality control here is critical.
39	Figure 22	Second shot of acceptable and unacceptable liner formations.
40		Checking and individual mark up of liners graded acceptable.
41		Energy absorption liners for the front facial protection sections of Bell Star.
42.	Figure 23	Every individual liner has cast shell size in this case D, Batch No., Inspector and date marked on it.
43	Figure 24	Shows the fibreglass material which is also marked Date, Inspector, Batch, Head Shell Size to be laid in the head form.
44.1		Head forms on the curing line -
	Figure 25	Car helmet with life support intake visible with results of severe abrasion and penetration procedure test gear.
.2		Bell Testing Laboratory - impact testing and penetration procedure test gear.
.3	Figure 26	Acceleration curve resulting from frontal crown impact on this polycarbonate helmet showing no damage to shell: there is a punctured hole in the liner and the trace goes off scale at over 900 g. Snell 75 impact used.
.5		Project leader Jack Ford and some of the range of test machines available at the training centre in Sacramento.
.6		Further selection of the machines available at the Training and Testing Centre, Sacramento.

7.		Honda 125 used by MRW at the Test Centre in Sacramento.
8.		Part of the range of safety helmets kept as part of the facilities for the Training and Testing Centre, Sacramento.
9.		Active check list for machines on the stocks of Test Centre, Sacramento.
10.		Part of the training layout marked on the test centre at Sacramento.
11.		View of some of the training stable circles: starting/stopping ramp: speed measuring equipment, control speed entry curves and avoidance range and warning lights, Sacramento.
12.		The new starting and stopping ramp at Sacramento.
13.		The "Y" shaped avoidance training markings at Sacramento
14.		Speed measurement, braking on a curve, avoidance layouts, Sacramento.
15.		Details of braking boxes and avoidance layouts.
16.		Braking and entry on a curve with speed measuring apparatus.
17.		Brake left and right avoidance test equipment.
18.		Braking on a curve marker light.
19.	Figure 18	Straight line braking distance markings
20.	Figure 18	Braking on a curve and braking in a straight line distance markings.
21.	Figure 18	Speed measurement, entry marking, braking on a curve, and braking in a straight line markings.
22.		Speedometer calibration measurement and indicator equipment.
23.		Starting on a hill test ramp.
24.		Typical testee on own machine
25.		DMV, California
26.		Small lecture area.