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Date: December 22, 2008

Brown Davis Automotive
47 Holloway Drive
Bayswater Vic 3153

Attention: David Brown

Dear David,

Reference: ROPS for mining vehicles

In regards to the installation of Roll Over Protective Structures (ROPS) to mining vehicles, follows is the assessment of the ROPS installed into a Ford Ranger vehicle.

The assessment is based upon the following parameters;

Vehicle Make/Model	Ford Ranger
Gross Vehicle Mass (GVM) (kg)	2870
Tested Mass (kg)	3068
Number of occupants	5
Number of roll hoops fitted	2

The ROPS is fabricated from CDS 350MPa high tensile steel comprising lateral roll hoops of 44.5mm and longitudinal members of 38.1mm outside diameter, 2.6mm wall thickness steel tube. Additional members of 25 x 25 x 3.0mm RHS are provided horizontally within the rear roll hoop, with further diagonal braces of the same material provided from the hip point of the rear roll hoop to the floorpan in the vicinity of the transmission tunnel.

The ROPS is designed to fit neatly within the passenger compartment of the vehicle, with specific consideration to reduce the risk to the vehicle occupants.

The vehicles intended to be fitted with the ROPS are used in various mining assets operated in remote areas of several countries. It is generally accepted that these vehicles are exposed to a higher risk of rollover incident than that would be encountered by most road vehicles.

Overall view of ROPS fitted to vehicle.

The assessment was performed using Strand 7 – a Finite Element Analysis (FEA) program. The FEA assessment allows the ROPS structure to be loaded without causing actual physical damage to the vehicle or the ROPS.

AEA was requested by Brown Davis Automotive to assess the ROPS to published Standards including that used by Shell Oil International.

The ROPS was subjected to loads in the vertical, longitudinal and transverse planes. The magnitude of these loads is 3 times the mass of the vehicle in the vertical and longitudinal planes and 1.5 times the vehicle mass in the transverse plane. The methodology and parameters of the testing is appended to this document.

Results

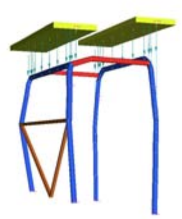
The FEA assessment of the applied loads determines the maximum deflection (plastic and elastic) of the members which are being loaded directly, with the internal stresses of the members indicated by the colour spectrum table shown on the left side of the load-stress diagram.

The deflections of the ROPS from the applied loads is summarised in the table below.

Vertical Load deflections	Longitudinal Load deflections	Transverse Load deflections
Front hoop 24mm/ Rear hoop 26mm	21mm	7mm

Follows are the specific results from the three load configurations.

Vertical load assessment



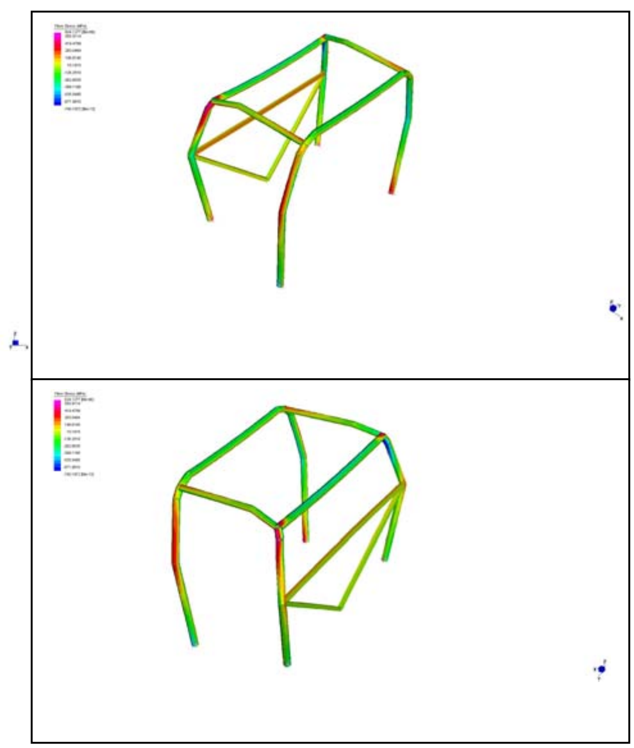
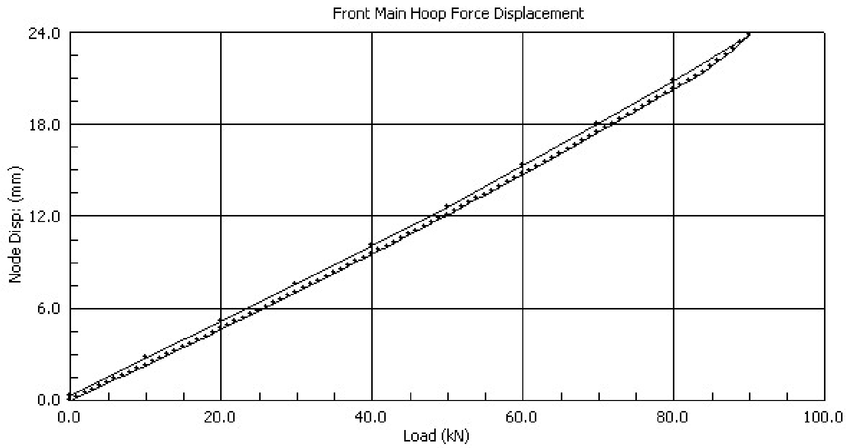


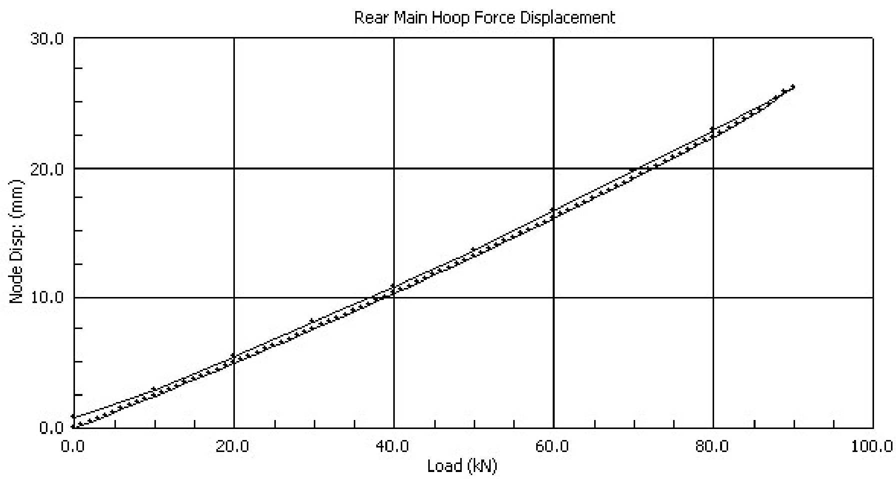
Image above shows model loading configuration.
Top right image shows rear roll hoop load stress diagram
Bottom right image shows front roll hoop load stress diagram

Roll hoops vertical load stress diagram



Load displacement graph of roll hoop.
Upper point on right side of trace is maximum deflection of the member.
Left side of trace shows plastic residual deformation of member.

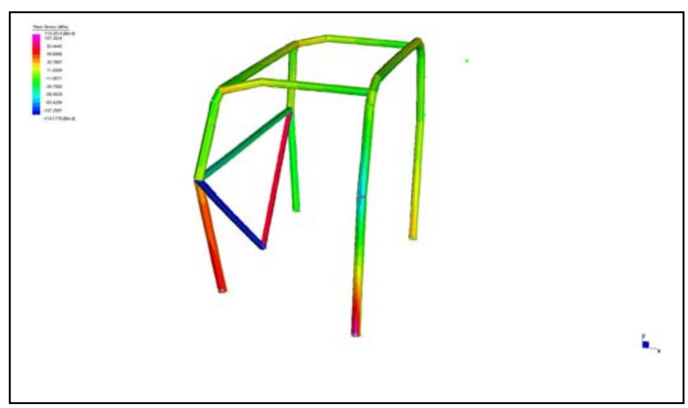
Front roll hoop vertical load – displacement graph



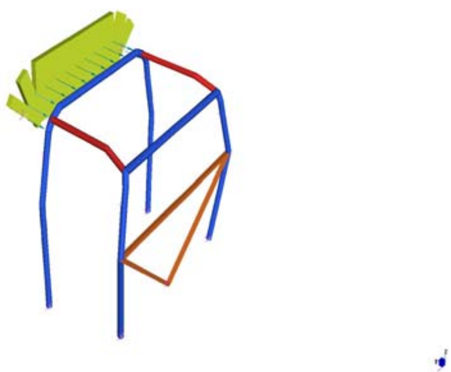
Load displacement graph of roll hoop.
Upper point on right side of trace is maximum deflection of the member.
Left side of trace shows plastic residual deformation of member.

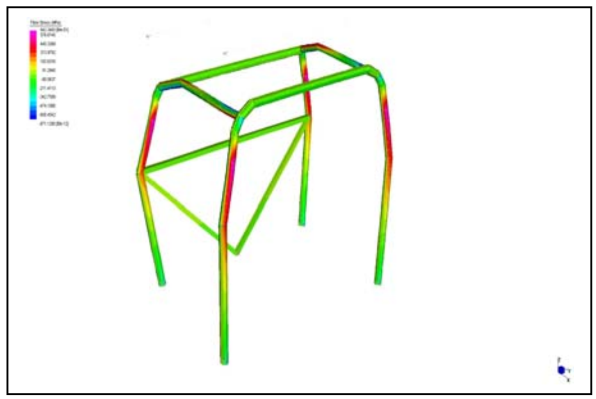
Rear roll hoop vertical load – displacement graph

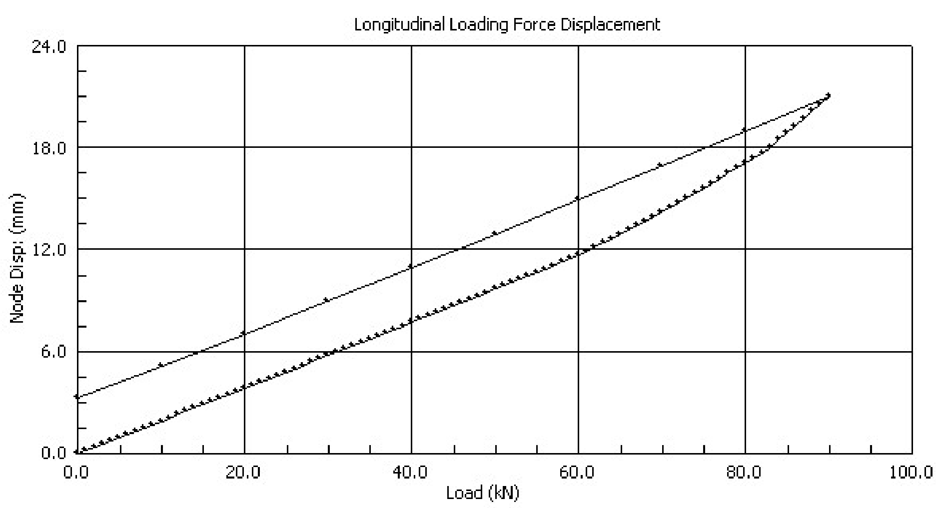
Lateral load assessment



Longitudinal load assessment







Load displacement graph for longitudinal load of roll hoop. Upper point on right side of trace is maximum deflection of the member.
Left side of trace shows plastic residual deformation of member.

Notes:

The ROPS is considered to have passed the above tests as the materials did not experience failure by fracture of a member or stresses beyond the material ultimate tensile stress during the loading in the above assessments.

The computations are based upon the vehicle weight and ROPS configuration as advised to AEA.

The ROPS must be fitted with a high density padding material for occupant impact protection.

This ROPS is considered to meet the intent of the Shell Oil International requirements and the FIA requirements as the applied loads do not make the ROPS members experience fracture, exceed the material Ultimate Tensile Strength or result in deflections exceeding 100mm.

Disclaimer

The above assessment by AEA does NOT state nor imply any of the following;

- The ROPS is safe. Using motor vehicles in off road environments is potentially dangerous and injuries &/or deaths may occur. It is not possible to design, construct or install a ROPS that can remove or eliminate any or all risks to the occupants of the vehicle due to the changeability and uncertainty of the circumstances in which the vehicle is used.
- The manufacture &/or installation of the ROPS is in accordance with Australian Standards, Australian Design Rules, State or other Regulations, accepted industry practices or other recommendations or guidelines.
- The design of the ROPS and quality of workmanship is adequate.
- The selection of welding consumables and/or the methods of weld preparation and performance are appropriate for the materials being welded including adherence to manufacturer's specifications.

Whilst the vehicle model type has been inspected, the individual vehicle and ROPS installation may not have been inspected by AEA or its' representatives.

Please contact the undersigned if you have any questions regarding this matter.

Yours sincerely,

Applied Engineering Analysis Pty. Ltd.

Jeff Watters
Chartered Professional Engineer

ROPS assessment methodology

The ROPS assessment is performed using the Finite Element Analysis software package Strand 7 where the ROPS structure is considered as beam elements, mounted to the floorpan at the base of each roll hoop.

The floor mountings of the ROPS are considered as moment applying connections.

No contribution to the strength of the ROPS is considered from the body shell itself other than the floorpan supporting the ROPS mounts.

Applied Engineering Analysis gained accreditation from the FIA – the world motorsport governing body – by demonstrating its ability to simulate deformations obtained in a "control" ROPS physical test. The FIA criteria required that the computer FEA simulation achieved results within 5% of the physical test results.

The FIA test methodology applies the loads to the ROPS using a simulated stamp of 350mm wide and of 40mm thickness. The length of the stamp is determined such that it spans the ROPS members by at least 100mm at each end. The stamp is used as it is described within the FIA assessment criteria and also best simulates contacting a semi solid object that will not yield on initial impact but will suffer minor deformation during the loading cycle.

The FIA test methodology has been adopted as it was developed from many years of testing and evaluating of motor racing rollover incidents. Whilst the speeds of motor racing vehicles is higher than that of vehicles used in mining assets, the mechanism of the rollover is similar. The Shell Oil International Standard is likely to have been derived from the FIA motor racing standards as used up until the mid 1990's before those standards were upgraded to include an upper A pillar loading.

The stamp is applied on the extremity of the ROPS and therefore the points of contact of the stamp on the ROPS will alter during the load cycle as the ROPS experiences plastic and elastic deformation.

In cases where the vehicle is equipped with more than one ROPS main hoop, the total vertical load is applied using multiple stamps, with the total load being applied proportionally over the stamps.

The total load is applied incrementally in approximately 100 steps until the maximum total load is achieved or until the material of the ROPS exceeds the ultimate tensile strength of the material. In such cases where the ultimate tensile strength of the material is exceeded, this is considered as a FAIL. The FIA criteria of deflection is adopted here also whereby the maximum total deflection – plastic and elastic deflection – is 100mm.

The recorded result is the total plastic deformation of the ROPS element being loaded. The elastic deformation of the ROPS element is displayed in the Force – Displacement graph shown in the results.

In circumstances where the ROPS is provided with additional body shell attachment to the pillars or seat belt sash anchorages, the assessment will attribute additional support for the ROPS in the longitudinal plane only and as a pin connection only. No compensation for seat belt loads is applied as the magnitude and direction of the loads of the ROPS and seat belts are opposite and therefore non compounding.

Additional assessments performed

AEA was requested to perform additional assessments on the ROPS, in particular, to consider a load of 0.75 of the GVM of the vehicle, applied laterally and immediately below the bend at the top of the main hoop/s.

This test methodology is derived from an ISO standard used in off road and agricultural equipment. The load is applied as a horizontal point load immediately below the top bend in the roll hoop.

The assessment performed by AEA was performed in 3 methods;

1/ Load of 0.75 GVM applied over both roll hoops
2/ Load of 0.75 GVM applied to front roll hoop
3/ Load of 0.75 GVM applied to rear roll hoop

The 3 test methods were considered as each method represents a foreseeable load condition that could be encountered by the ROPS.

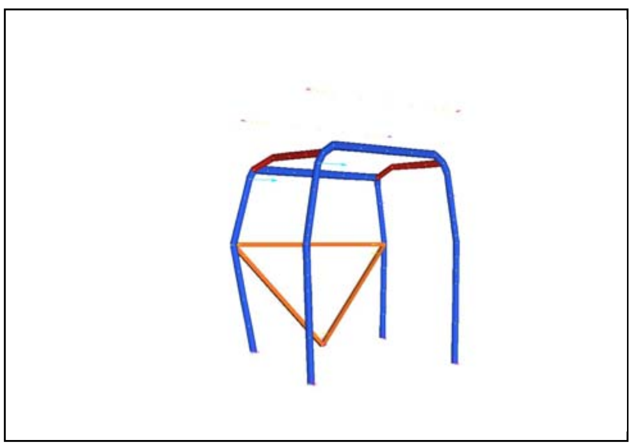
Results

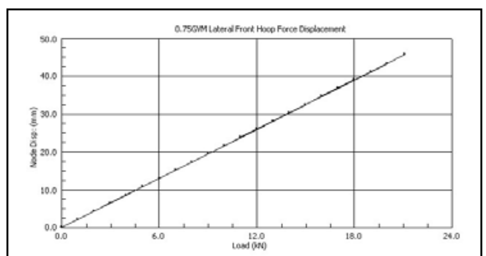
The deflections of the ROPS from the applied loads is summarised in the table below.

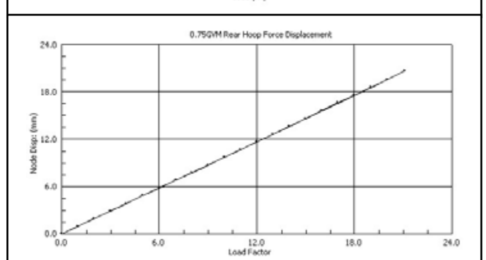
Load applied	Front Roll Hoop deflection mm	Rear Roll Hoop deflection mm
Both Roll Hoops	46	21
Front Roll Hoop	117	20
Rear Roll Hoop	18	22

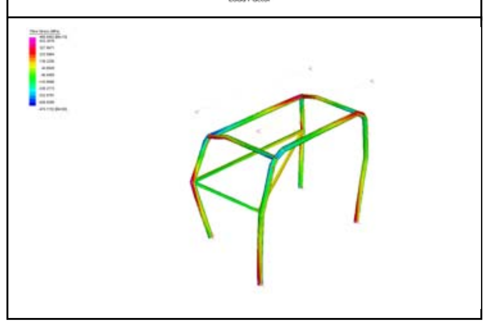
Follows are the specific results from the three load configurations.

Load of 0.75 GVM applied over both roll hoops





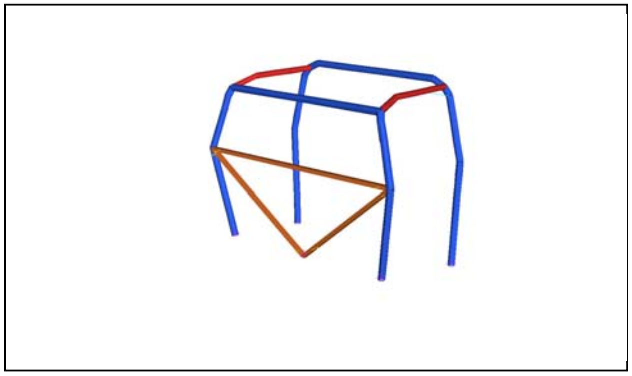


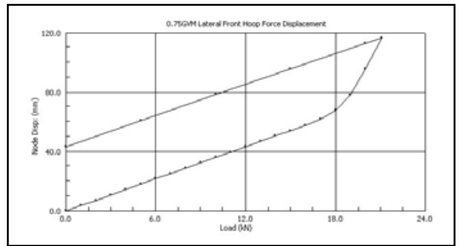


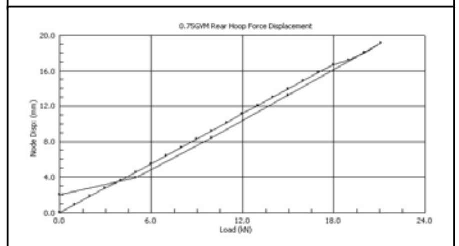
Top right graph – front hoop, force displacement
Centre right graph – rear hoop, force displacement

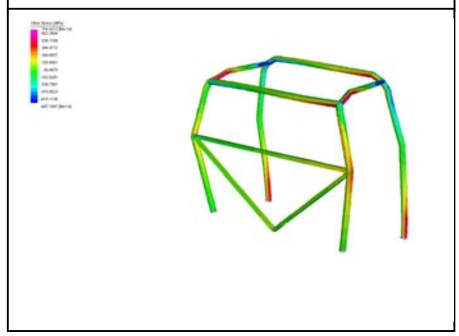
Lower right – Load condition stress plot

Load of 0.75 GVM applied to front roll hoop





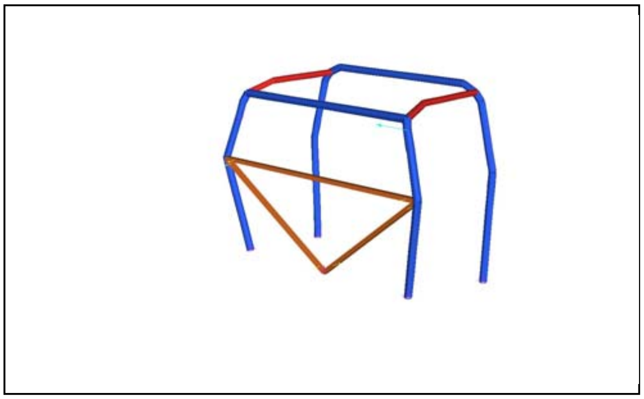


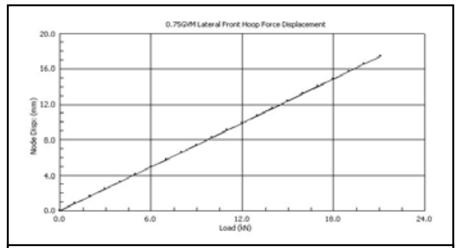


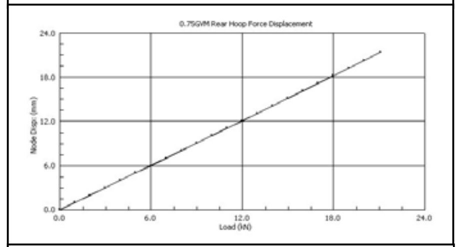
Top right graph – front hoop, force displacement
Centre right graph – rear hoop, force displacement

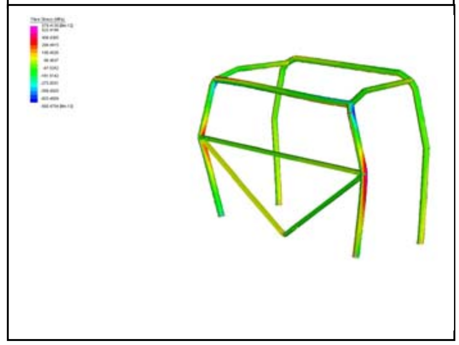
Lower right – Load condition stress plot

Load of 0.75 GVM applied to rear roll hoop









Top right graph – front hoop, force displacement
Centre right graph – rear hoop, force displacement

Lower right – Load condition stress plot

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Date: August 2008

Jeff WATTERS
Chartered Professional Engineer

Academic Qualifications

Bachelor of Engineering (Mechanical)
Swinburne Institute of Technology

Professional Experience

1992: **Applied Engineering Analysis Pty. Ltd.,** Bayswater, Victoria.
September 1992 to present.

Principal of Engineering consultancy. Specialising in design, assessment and testing of vehicles. Expert witness. FIA/CAMS Accredited ROPS assessor. Mechanical Engineering consulting/ Project management. (Major Projects; DECA Rollover Protection, Ambulance Spinal Board Mount & Defibrillator Mount/ Steering conversion assessments, Victoria Police Replacement Booze Bus project, Design of wheelchair accessible vehicles, ROPS assessments, Several CPA's, Specialist Vehicles.)
Recognised Engineering Signatory: Victoria (VASS) 1025., New South Wales, South Australia, Queensland, Western Australia, Northern Territory.

1990: **Transport Industry Consultants Pty. Ltd**., Hawthorn, Victoria.
March 1990 to August 1992.

Employed as Professional Engineer in consultancy practice, specialising in vehicle design, testing and assessment. Preparation of expert witness reports. (Major Projects; Ambulance Rollover Protection & Braking Assessment, Several CPA's, Specialist Vehicles, Pontoon Mounted Drilling Rig, Over-Dimensional Transport.)

1988: **Millsom Hoists Pty. Ltd**., Blackburn, Victoria.
July 1988 to March 1990.

Employed as Project Engineer, responsible for project management, detailed design, structural computations and supervision of manufacture, installation and commissioning of overhead travelling cranes and steel structures. (Major Projects; Hyatt Hotel Food Court Dome, Cleaning Gantry, President Motel Maintenance Crane, 101 Collins Street Fascia Test Rig)

1987: **Ogden Industries**, Huntingdale, Victoria,
July 1987 to January 1988.

Employed as temporary cadet Engineer, involved in investigations of mechanical systems and Engineering design.

1986: **CSR Gyprock**, Yarraville, Victoria.
February 1986 to July 1986.

Employed as temporary cadet Engineer, assistant to Plant Engineer.

Membership of Professional Bodies

The Institution of Engineers, Australia. (Member)

Society of Automotive Engineers, Australasia. (Member)