Disc Brakes For Heavy Trucks

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"BRAKES AND SAFETY"

LET ME BEGIN WITH AN ASSUMPTION

(FIG. 1)

THAT'S HOW IT COULD HAVE BEEN. MEN NEEDED BRAKES URGENTLY. COMFORT AND SCARE HAVE ALWAYS BEEN STRONG MOTIVATIONS FOR THE HUMAN CREATIVITY.

LET US MAKE A JUMP IN TIME. IN AROUND 1925 AIR BRAKES WERE INTRODUCED INTO COMMERCIAL VEHICLES. AT THAT TIME THERE WAS A CLEAR INSTRUCTION "BEFORE COMMENCING DOWNHILL, STOP THE VEHICLE AND ENGAGE 1ST GEAR".

AFTERWARDS THE SAFETY STANDARD HAS CONTINUOUSLY IMPROVED UP TO THE INTRODUCTION OF DISC BRAKES.

AS EARLY AS 1979 MAN DEVELOPMENT ENGINEERS REALISED THAT SUBSTANTIAL CHANGES NEEDED TO BE INTRODUCED TO THE THEN EXISTING BRAKE SYSTEM WHILST ALREADY BEING DRUM BRAKES, STILL CONSISTED TO SOME EXTENT OF AIR HYDRAULIC COMBINATIONS.

THIS CERTAINLY APPLIED TO A LARGE NUMBER OF VEHICLES AS FAR AS FRONT AXLE BRAKES WERE CONCERNED.

(FIG. 2)

SINCE THEN, APART FROM CHANGING TO FULL AIR BRAKES, ABS WAS ANOTHER MILESTONE IN THE DEVELOPMENT OF THE BRAKE SYSTEM. NOW WE HAVE FULL AIR OPERATED DISC BRAKES.

IN EUROPE, HOME OF A NUMBER OF MAJOR VEHICLE MANUFACTURERS, THE EC DIRECTIVE 71/320/EEC IS THE STANDARD APPLICABLE TO HIGH SPEED COMMERCIAL VEHICLE BRAKE SYSTEMS.

THIS STANDARD BEING PASSED INTO THE NATIONAL LEGISLATION OF EACH COUNTRY AND THEREFORE INTRODUCED ALSO INTO VEHICLES BEING SOLD INTO NZ COVERS THE FOLLOWING MAIN ISSUES:

- MINIMUM RETARDATION RATES AND MAXIMUM BRAKING DISTANCES
- EFFECTIVENESS OF THE BRAKE SYSTEM AT HIGHER SPEEDS
- EFFECTIVENESS WHEN BRAKES ARE HOT
- EFFECTIVENESS UNDER PROLONGED BRAKING (DOWN HILLS)
- DISTRIBUTION OF BRAKE FORCES TO THE VEHICLE AXLES
- DISTRIBUTION OF BRAKE FORCES IN ROAD TRAINS AND SEMI-TRAILER OPERATIONS (CONDITIONS OF COMPATIBILITY)

UNLIKE OLDER REGULATIONS THIS NEW DIRECTIVE FOCUSES PARTICULARLY ON THE DYNAMIC CONDITIONS DURING BRAKING, THE DISTRIBUTION OF BRAKE FORCES BETWEEN THE AXLES OF THE INDIVIDUAL VEHICLE AND THE ALLOCATION OF BRAKE FORCES BETWEEN THE PRIME MOVER AND TRAILER OR SEMI-TRAILER.

THE DESIGN ENGINEERS THEREFORE MUST BRING EVIDENCE THAT THE BRAKE SYSTEMS COMPLY WITH THE RELEVANT LIMIT CURVES.

IN VEHICLES WITH ANTI-LOCK BRAKING SYSTEM, OR BETTER KNOWN AS ABS, CALCULATORY PROVE THAT THE FRICTION CURVES ARE COMPLIED WITH; IN OTHER WORDS PROOF OF THE DISTRIBUTION TO THE VEHICLE AXLES CAN BE WAIVED.

AS YOU ALL KNOW ABS PREVENTS THE WHEELS FROM LOCKING UP AND ENSURES DIRECTIONAL STABILITY DURING BRAKING.

THESE DAYS, BRAKE SYSTEMS COMPLYING WITH EC LEGISLATION NORMALLY MORE THAN SATISFY THE REGULATIONS. THIS IS PROOF OF INTENSIVE FURTHER DEVELOPMENT OF COMMERCIAL VEHICLE BRAKE SYSTEMS IN THE LAST FEW YEARS AND OF THE INCREASE IN ACTIVE VEHICLE SAFETY.

THE INTRODUCTION OF DISC BRAKES IN TRUCKS AND BUSES HAS PLAYED A MAJOR ROLE HERE. IT SHOULD BE STRESSED ABOVE ALL THAT DISC BRAKES ARE EXTREMELY RESISTANT TO THERMAL STRESS AND PROLONGED LOADS AND ARE MORE RESISTANT TO DIFFERENCES IN COEFFICIENTS OF FRICTION THAN DRUM BRAKES.

(FIG. 3)

APART FROM THE DRIVER'S REACTION A LARGE NUMBER OF DIFFERENT PARAMETERS ARE IMPORTANT FOR BRAKING AND FOR THE BRAKING DISTANCES ACHIEVED, ESPECIALLY IN EMERGENCY SITUATIONS.

WHILE THE THERMAL RESISTANCE OF MODERN BRAKE SYSTEMS IS NO LONGER NECESSARILY A CRITICAL LIMITATION MORE ATTENTION MUST BE DEVOTED ABOVE ALL TO THE INFLUENCES OF THE ADHESION COEFFICIENT BETWEEN TYRES AND ROAD.

(FIG. 4)

THE NON-SLIP PROPERTIES OF CERTAIN TYRES IN WET CONDITIONS IN PARTICULAR MUST BE SUBJECTED TO CRITICAL APPRAISAL, NOT LEAST BECAUSE THE EFFECTS OF CERTAIN OPTIMISATION PARAMETERS TEND TO COUNTERACT EACH OTHER.

FOR EXAMPLE, TYRE SERVICE LIFE OR NOISE BEHAVIOUR.

RECENTLY MAN MADE AVAILABLE SEVERAL TRUCKS AND BUSES TO BE USED IN A BRAKE TEST MONITORED BY GERMAN AUTHORITIES RESPONSIBLE FOR REGULATIONS AND ALSO TO ENSURE THAT THEY CORRESPOND TO THE SERIES PRODUCTION STATUS.

THE VEHICLES TESTED WERE EQUIPPED WITH A MODERN MULTI CHANNEL MEASURING SYSTEM WITH WHICH THE BRAKE MEASUREMENTS CAN BE QUICKLY EVALUATED ON A PC WITH SPECIAL SOFTWARE.

WE HAVE A VIDEO WHICH WE WILL SHOW TO YOU GIVING DETAIL OF THE EVALUATION WHICH IN PARTICULAR RELATE TO:

- BRAKING DISTANCE
- BRAKING RETARDATION
- BRAKE PRESSURE, AND
- BRAKE DISC TEMPERATURE

"VIDEO"

LET ME NOW ADDRESS THE PHYSICS OF BRAKING AND BRAKING POWER AND BRAKE ENERGY. THESE ARE ALL VERY IMPORTANT FACTORS LEADING TO THE DEVELOPMENT OF DISC BRAKES AND THE DECISION TO EQUIP MORE AND MORE VEHICLES WITH DISC BRAKES EITHER ON SELECTED AXLES OR, DEPENDING ON MODEL, ON EACH AXLE.

COMMERCIAL VEHICLE BRAKES ARE BECOMING MORE AND MORE POWERFUL ALL THE TIME.

(FIG. 5)

THIS IS A DEVELOPMENT WHICH HAS GONE ALMOST UNNOTICED BY THE PUBLIC EYE.

A RISE IN ENGINE POWER SUCH AS THAT IN THE LAST TEN YEARS FROM APPROXIMATELY 300-360 HP TO THE PRESENT LEVEL OF 320-600 HP IS CLOSELY FOLLOWED BY TRANSPORT COMPANIES, DRIVERS AND THE TRADE PRESS AND GIVEN CORRESPONDING COMMENT.

HERE HOWEVER WE MUST TAKE A GOOD LOOK OF WHAT A BRAKE ACTUALLY HAS TO DO.

THE POWER OF THE ENGINE IS NEEDED TO ACCELERATE A VEHICLE. A HIGH ENGINE OUTPUT ALLOWS A VEHICLE COMBINATION TO REACH ITS CRUISING SPEED QUICKLY. A 40 TONNE COMBINATION ACCELERATES FROM 0 TO 80 KM/H IN APPROXIMATELY 45 SECONDS. THE POWER REQUIRED IS APPROXIMATELY 450-460 HP.

THE SAME COMBINATION WILL DECELERATE FROM 80 KM/H TO 0 IN 3 SECONDS, BUT FOR THIS IT NEEDS A POWER OF 6800 KW, THIS BRAKING POWER CORRESPONDS TO A TOTAL ENGINE OUTPUT OF 18 PRIME MOVERS WITH 500 HP EACH.
THIS POWER NOW MUST BE SUPPLIED BY RELATIVELY SMALL PARTS OF THE BRAKE.

THE KINETIC ENERGY OF THE VEHICLE IS THEREBY CONVERTED INTO HEAT. AND THIS HAPPENS DURING EVERY BRAKING PROCEDURE.

TWO CRITERIA DECIDE THE QUALITY OF A BRAKE.

1. THE BRAKING DISTANCE,

2. THE STABILITY UNDER REPEATED BRAKING.

THE BRAKING DISTANCE IS IN PHYSICAL TERMS DETERMINED SOLELY BY THE STARTING SPEED OF THE VEHICLE AND BY THE RETARDATION. THIS MEANS THE BRAKING SYSTEM DISTANCE IS INDEPENDENT OF THE MASS OF THE VEHICLE.

THERE ARE STANDARD FACTORS AFFECTING THE BRAKING DISTANCE.

(FIG. 6)

IN REALITY HOWEVER THE ACTUAL BRAKING DISTANCE DEPENDS ON TWO FURTHER MAJOR FACTORS:

- THE SPEED WITH WHICH THE DRIVER ACTUATES THE BRAKE PEDAL
- THE TIME REQUIRED BY THE BRAKE SYSTEM TO BUILD UP THE FULL BRAKE PRESSURE IN THE WHEEL BRAKE CYLINDERS

IF THE BRAKE PEDAL IS DEPRESSED QUICKLY THE BRAKING DISTANCE WILL BE SHORTENED AS THE BRAKE PRESSURE CAN BE BUILT UP MORE QUICKLY AND THE FULL BRAKING FORCE WILL BE AVAILABLE EARLIER.

HOWEVER THE BRAKING DISTANCE ALSO DEPENDS ON THE DISTRIBUTION OF THE BRAKE FORCE TO THE INDIVIDUAL WHEELS AND ON THE MAXIMUM BRAKE FORCE THAT CAN BE TRANSMITTED ON THE BASIS OF THE FRICTION BETWEEN TYRES AND ROAD SURFACE.

THE STABILITY OF A BRAKE DEPENDS ON THE SPEED OF ENERGY CONVERSION. AS ALL ENERGY IS CONVERTED INTO HEAT, A BRAKE IS THE MORE STABLE THE SOONER IT IS ABLE TO DISSIPATE THE HEAT GENERATED TO THE SURROUNDINGS.

(FIG. 7)

FOR A MINOR BRAKING PROCEDURE TO ADJUST SPEED TO THE FLOW OF TRAFFIC ONLY A SMALL AMOUNT OF BRAKE ENERGY IS INVOLVED AND THE BRAKE RETAINS ALMOST ITS ENTIRE RESERVES FOR STORING HEAT.

FOR A SINGLE EMERGENCY STOP THIS POTENTIAL IS NOT SIGNIFICANTLY REDUCED EITHER, IT IS THEREFORE POSSIBLE TO MAKE SEVERAL EMERGENCY STOPS IN QUICK SUCCESSION WITHOUT ANY PROBLEM AND WITH FULL EFFECT.

FOR DOWNHILL BRAKING, IN OTHER WORDS KEEPING THE SPEED CONSTANT BY MEANS OF THE SERVICE BRAKE, THE BRAKES CAPACITY FOR HEAT STORAGE IS HOWEVER VERY QUICKLY EXHAUSTED.

AS ENERGY IS CONSTANTLY BEING CONVERTED THE HEAT CAN NO LONGER BE DISSIPATED TO THE SURROUNDINGS.

THE HEAT IS DISSIPATED PRIMARILY VIA THE SURFACE OF THE BRAKE BY RADIATION AND CONVECTION, WHILE THE REMAINDER PASSES TO THE WHEEL HUBS AND AXLES BY CONDUCTION.

LET US NOW LOOK AT THE TYPES OF WHEEL BRAKES AND WHERE ALL THIS LEADS TO.

IN COMMERCIAL VEHICLES TWO TYPES OF BRAKES ARE MOST COMMONLY USED:

(FIG. 8)

- DRUM BRAKES

(FIG. 9)

- DISC BRAKES

THE TYPE WHICH HAS FOUND MOST WIDESPREAD USE IS THE DRUM BRAKE DESIGNED AS A SO-CALLED SIMPLEX BRAKE.
THE ACTUATION BY USE OF AN S-CAM HAS THE ADVANTAGE OF EQUAL LINING WEAR ON BOTH THE LEADING AND TRAILING SHOES WHICH IS DICTATED BY THE FIXED ACTUATION.

THE SERVICE LIVES ARE CORRESPONDINGLY HIGH. THE ACTUATING MECHANISM VIA DIAPHRAGM CYLINDERS AND AUTOMATIC SLACK ADJUSTERS IS SIMPLE, RELIABLE AND NOT SUSCEPTIBLE TO THE EFFECTS OF HEAT.

THE DISC BRAKE BEING A FLOATING CALLIPER TYPE, HAS THE BASIC ADVANTAGE OVER THE DRUM BRAKE THAT THE BRAKE AFFECT CAN BE METERED BETTER. ITS CHARACTERISTIC BEHAVIOUR TOO IS EXTREMELY CONSTANT, ON THE OTHER HAND IT IS MORE EXPENSIVE.

THE PROBLEM OF SHORTER SERVICE LIFE ENCOUNTERED IN THE INITIAL STAGES OF DISC BRAKE DEVELOPMENT HAS BEEN COMPLETELY SOLVED BY IMPROVEMENT OF THE PAD MATERIAL QUALITY.

(FIG. 10)
THE DISC BRAKE HEATS UP MORE IN A SINGLE BRAKING PROCEDURE THAN DOES THE DRUM BRAKE, BUT IT CAN ALSO WITHSTAND HIGHER TEMPERATURES THAN THE DRUM BRAKE.

THIS IS DUE PRIMARILY TO THE VERY COMPACT DESIGN OF THE DISC BRAKE PADS WHICH REQUIRE FEWER BINDING AGENTS AND ARE THEREFORE MORE RESISTANT TO HIGH TEMPERATURES.

IN RELATION TO THE TITLE OF THIS PRESENTATION, WHAT DOES IT MEAN? IN SIMPLE TERMS: "DISC BRAKES RAISE THE LEVEL OF DRIVING SAFETY IN COMMERCIAL VEHICLES".

TO LET OWNERS OF TRUCKS AND BUSES REGULARLY COME INTO THE ENJOYMENT OF PROGRESS IN THE ENGINEERING OF COMMERCIAL VEHICLES BY MEANS OF CONTINUOUS FURTHER DEVELOPMENT, MAN BEGAN TO INTRODUCE DISC BRAKES ON FRONT AXLES OF LUXURY COACHES BACK IN 1991.

IN THE CASE OF TRUCKS IT WAS THE THEN FLAGSHIP WITH A 500 HP ENGINE TO RECEIVE DISC BRAKES ON THE FRONT AXLE IN 1992.

AT THAT TIME THIS VEHICLE AND, IN PARTICULAR, THE INTRODUCTION OF DISC BRAKES ATTRACTED GREAT ATTENTION DURING THE LAUNCH AT THE INTERNATIONAL AUTOMOBILE EXHIBITION IN HANOVER IN 1992.

IN THE MEANTIME THE SUCCESS OF THIS DEVELOPMENT HAS BEEN SUCH THAT DISC BRAKES ARE NOW PART OF THE SERIES PRODUCTION OF THE ENTIRE MAN TRUCK AND BUS RANGES.

BUSES, COACHES AND LIGHT TO MEDIUM DISTRIBUTION TRUCKS ARE NOW AVAILABLE WITH DISC BRAKES FITTED ALL ROUND. IN THE MEDIUM TO HEAVY AND HEAVY DUTY TRUCK RANGES, DISC BRAKES ARE PRESENTLY FITTED ONLY TO THE FRONT AXLES WHICH HAVE TO TAKE MOST OF THE STRESS DURING BRAKING.

EXCEPTIONS STILL ARE HIGH MOBILITY OR SPECIAL OFF-ROAD VEHICLES.

(FIG. 11)

THE ADVANTAGES OF DISC BRAKES OVER THE PROVEN DRUM BRAKES ARE TO BE FOUND IN THEIR LONG TERM STABILITY AND ALL IN ALL IN THEIR MUCH HIGHER BRAKE POWER.

IN VIEW OF THE CONSTANT INCREASE IN ENGINE RATINGS IN COMMERCIAL VEHICLES IRRESPECTIVE OF CATEGORY, DISC BRAKES ARE A DICTATE OF THE HOUR FOR IMPROVING RIDE SAFETY AND SAFETY IN TRAFFIC.

WHAT CAN BE GAINED IN BRAKING DISTANCE

(FIG. 12)

THE GAIN IN BRAKING DISTANCE IS QUITE SIGNIFICANT IF ONE LOOKS AT THE PERFORMANCE OF A HEAVY DUTY PRIME MOVER WITH DISC BRAKES ON THE FRONT AXLE ONLY AND A TRAILER WITH CONVENTIONAL DRUM BRAKES IN COMPARISON TO A TRAILER WITH DISC BRAKES.

IMPROVEMENTS OF 22 TO 28 % IN RELATION TO THE LEGALLY PERMISSIBLE BRAKING DISTANCE OF A 40 TONNE COMBINATION IS POSSIBLE.

A FURTHER GAIN IN BRAKING DISTANCE IS POSSIBLE BY REDUCING THE RESPONSE TIME AND PRESSURE BUILT UP TIME WITH THE INTRODUCTION OF ELECTRONIC BRAKE SIGNALS (EBS).

ON A CONVENTIONAL PRIME MOVER / TRAILER COMBINATION THE AIR SIGNAL HAS TO TRAVEL CLOSE ENOUGH TO 20 METRES. THIS RESULTS INTO A TIME DELAY OF 0.15 TO 0.2 SECONDS. WITH EBS THE BUILT UP SPEED OF BRAKE PRESSURE CAN BE INCREASED AS THE FOLLOWING DIAGRAM INDICATES.

(FIG. 13)

FURTHER PLUSES OF THE DISC BRAKE COMPARED TO THE DRUM BRAKE SYSTEMS ARE THAT THEY CAN BE APPLIED MORE SENSITIVELY

AND THEY ARE EASIER TO REPAIR WHEN THE PADS OR DISCS HAVE TO BE CHANGED. VISITS TO THE WORKSHOP ARE SHORTENED AND REPAIR COSTS CUT. IN TIMES OF INTENSIFYING COMPETITION IN THE ROAD HAULAGE BUSINESS THESE ARE ADVANTAGES THAT SHOULD NOT BE UNDERESTIMATED.

WITH THE INTRODUCTION OF DISC BRAKES INTO COMMERCIAL VEHICLES MAN ALSO DECIDED TO FIT LARGER BRAKE CYLINDERS TO INCREASE THE BRAKE FORCES AND, AT THE SAME TIME RAISED THE SYSTEM PRESSURE FROM 8.5 TO 10 BAR. THIS CREATED THE ESSENTIAL CONDITIONS FOR GREATER BRAKING SAFETY.

THE DECISION OF THE ENGINEERING DEPARTMENT TO START INTRODUCING DISC BRAKES IN TRUCKS AND BUSES ON THE FRONT AXLE WAS MADE ON THE BASIS OF THE LAWS OF PHYSICS, OR MORE PRECISELY BECAUSE OF THE SHIFT IN THE DYNAMIC AXLE LOAD DURING BRAKING.

LET'S LOOK AT A SIMPLE EXAMPLE

(FIG. 14).

IN A TWO AXLE TRUCK AN EMERGENCY STOP INCREASES THE FRONT AXLE LOAD UP TO 12 TONNE. IN A PRIME MOVER/TRAILER COMBINATION THE FRONT AXLE BRAKES HAVE TO COPE WITH A LOAD OF MORE THAN 13 TONNE.

THAT IS ONE THIRD OF THE GROSS COMBINATION MASS. AT THE SAME TIME IT MUST BE THE OBJECTIVE OF BRAKE ENGINEERING TO PUT UNIFORM BRAKE SYSTEMS ON ALL WHEELS OF COMMERCIAL VEHICLES TO EXPLOIT THE ADVANTAGES OF STANDARDISATION.
THIS MESSAGE SHOULD ALSO BE PUT LOUD AND CLEARLY TO THE TRAILER MANUFACTURING INDUSTRY.

HERE IS ANOTHER CHALLENGE AND IF PEOPLE FROM THE INSURANCE INDUSTRY ARE PRESENT IT IS ESPECIALLY ADDRESSED TO THEM.
"LOWER INSURANCE PREMIUMS FOR HIGHER TECHNICAL STANDARDS".

IN EUROPE, HERE IN PARTICULAR IN GERMANY, IT WORKS. IN RECOGNITION OF THE WELL KNOWN HIGH GENERAL STANDARD OF EQUIPMENT SUCH AS OFFERED BY MAN PARTICULAR WITH REGARD TO ACTIVE AND PASSIVE SAFETY, THE GERMAN INDUSTRY LIABILITY INSURANCE ASSOCIATION HAS REDUCED BY 13% THE INSURANCE PREMIUM FOR A HEAVY DUTY TRUCK OR PRIME MOVER FITTED IN SERIES PRODUCTION SINCE 1994 WITH DISC BRAKES AND HIGH SAFETY RUNNING GEAR.

THIS POSITIVE PREMIUM RISK APPLIES NOT ONLY TO INDIVIDUAL VEHICLES BUT IN ACCORDANCE WITH INSURANCE AGREEMENTS TO ENTIRE VEHICLE FLEETS TOO.

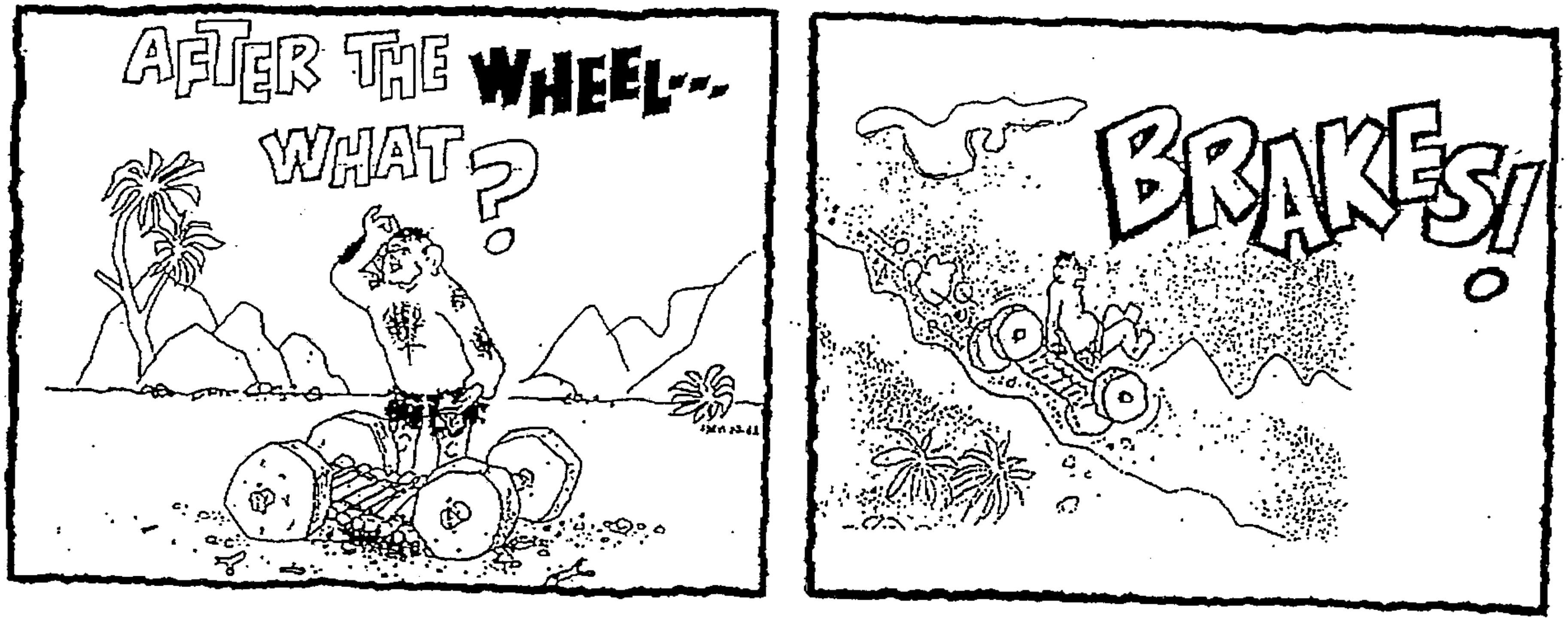
ASSUMING INSURANCE COSTS BETWEEN GERMANY AND NEW ZEALAND WOULD BE SIMILAR, A 13% REDUCTION WOULD MEAN A SAVING OF AROUND NZ$1,800 PER VEHICLE. FOR LARGE FLEETS THERE IS THUS A CONSIDERABLE POTENTIAL SAVING TO BE MADE.

IN CONCLUSION LET ME SUMMARISE THE MOST IMPORTANT FEATURES AND THEREFORE GOOD REASON TO HAVE DISC BRAKES IN ALL COMMERCIAL VEHICLES:

- LOWER DROP IN BRAKING ACTION WITH HIGHER LOAD. IN OTHER WORDS LOW FADING.
- HIGHER BRAKE POWER AS HIGHER TEMPERATURES ARE POSSIBLE.
- BETTER DOSAGE.
- LOW BRAKING ACTION FLUCTUATIONS, THUS BETTER STRAIGHT RUN DURING BRAKING.
- QUICKER BRAKE LINING CHANGE.
- LOWER MAINTENANCE COSTS.
- HIGHER VEHICLE AVAILABILITY.
- SERVICE LIFE OF BRAKE LININGS IS NOW ROUGHLY THE SAME AS THOSE OF DRUM BRAKES.

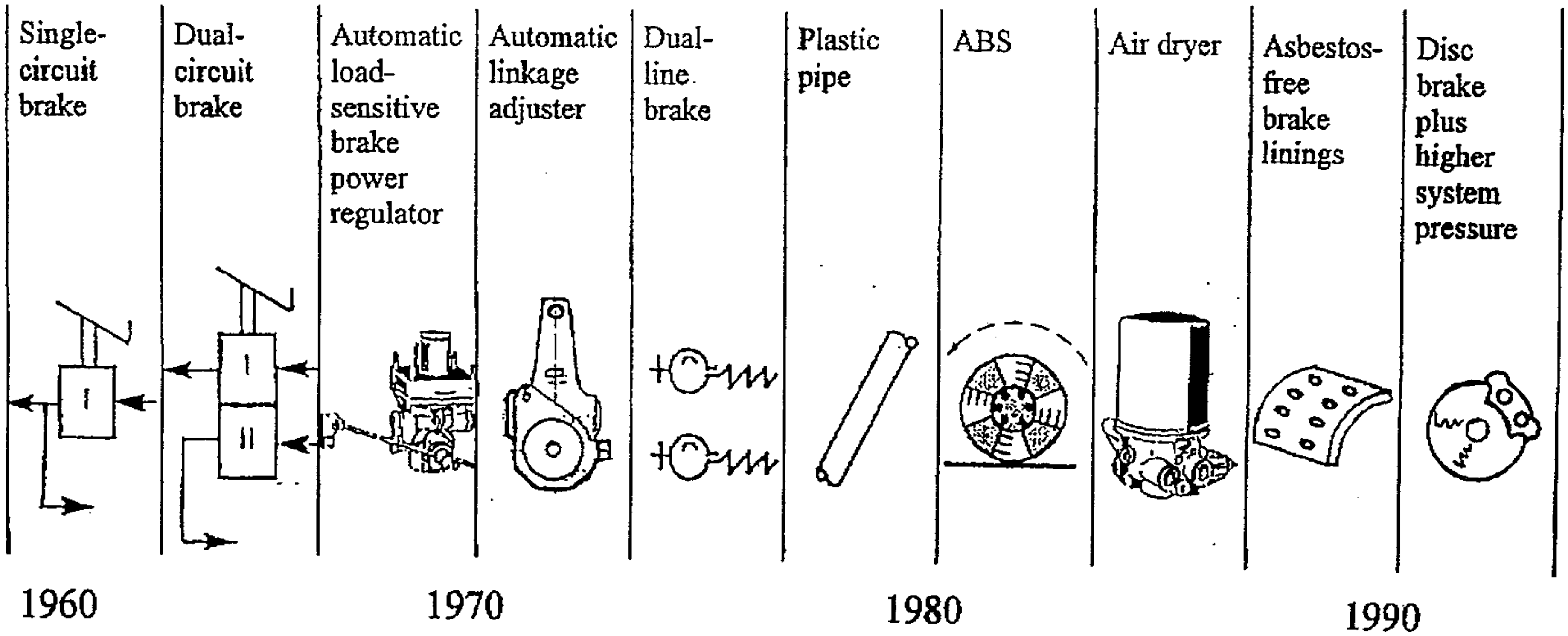
ON OUR HEAVY DUTY RANGE WITH COMPACT WHEEL BEARING HUB UNIT, WHEEL BEARINGS DO NOT HAVE TO BE DISASSEMBLED ANY MORE WHEN CHANGING BRAKE DISCS, WHICH MEANS A FURTHER REDUCTION IN DOWNTIME.

NOTWITHSTANDING THE ADVANTAGES OF DISC BRAKES, THE BORDER LINE FOR MAXIMUM BRAKING EFFICIENCY IS TO A VERY LARGE EXTENT DICTATED BY THE CONTACT BETWEEN THE TYRE AND THE ROAD SURFACE, AND IN ADDITION,
"THE GREATEST INFLUENCE AS FAR AS BRAKE PERFORMANCE AND BRAKING DISTANCE IS CONCERNED DOES HOWEVER STILL REST WITH THE DRIVERS".



1

The great realisation



2

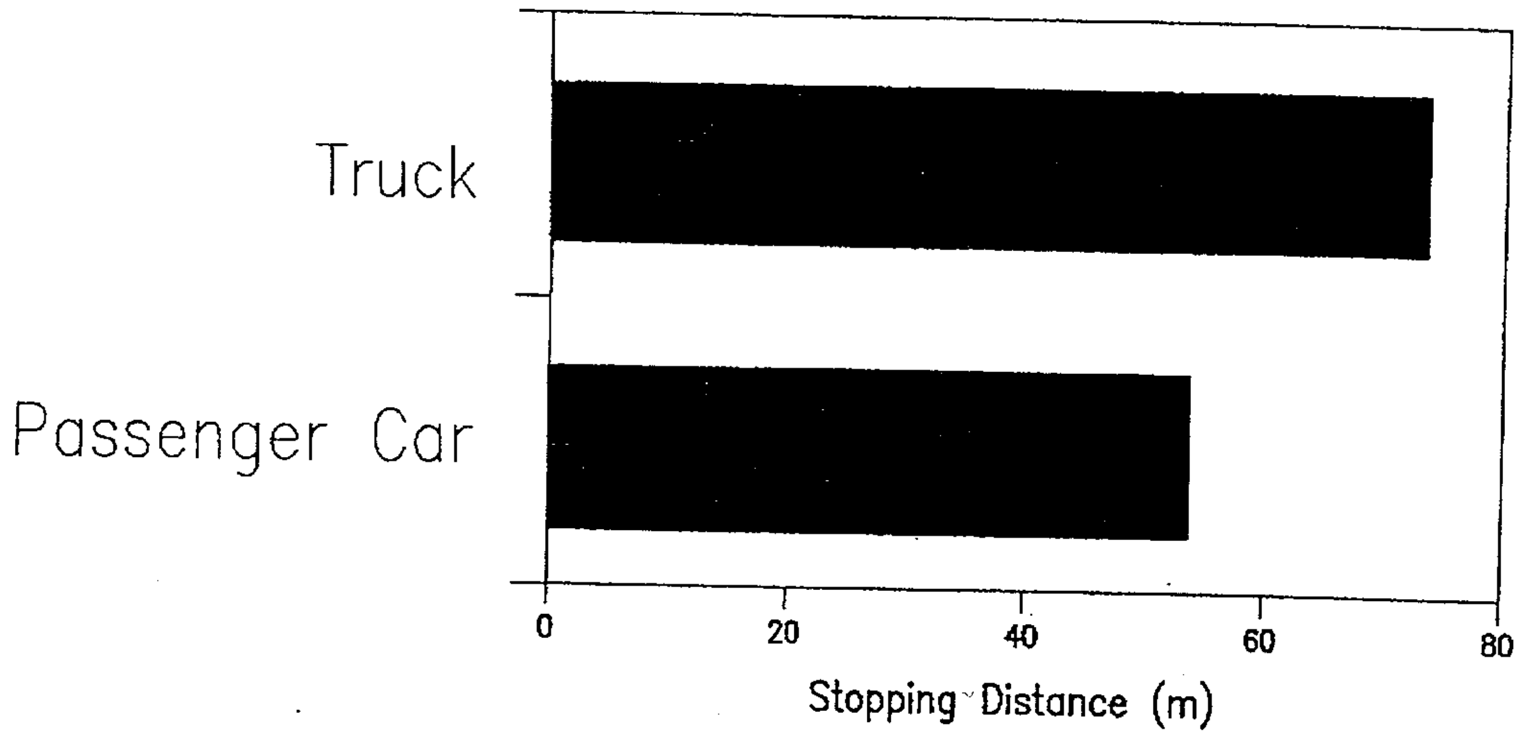
History of the development of commercial vehicle brake system

- Driver's Reaction
- Adhesion levels between tyre and road surface
- Distribution of braking among the axles of vehicles
- Compatibility between towing vehicles and trailers
- Capability of anti-lock systems
- Response time of braking system
- Capacity of hot brakes
- General technical condition of brake system

Factors of Influence at Braking

MAN

Stopping distances of truck and passenger car at 80 km/h
Adhesion coefficient (wet surface) passenger car: 0.6
Adhesion coefficient (wet surface) truck: 0.4



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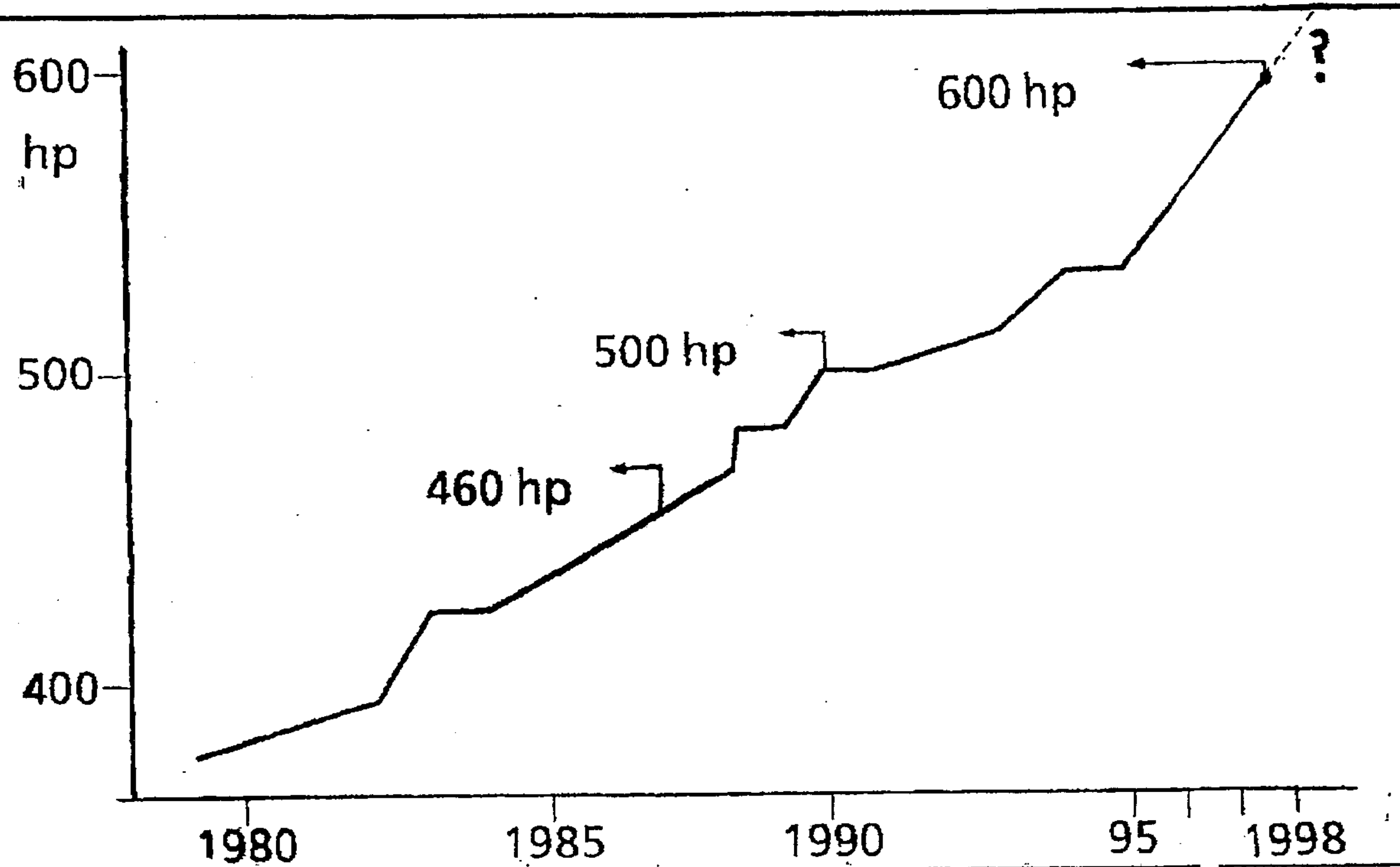
Adhesion between Tyre and Road Surface



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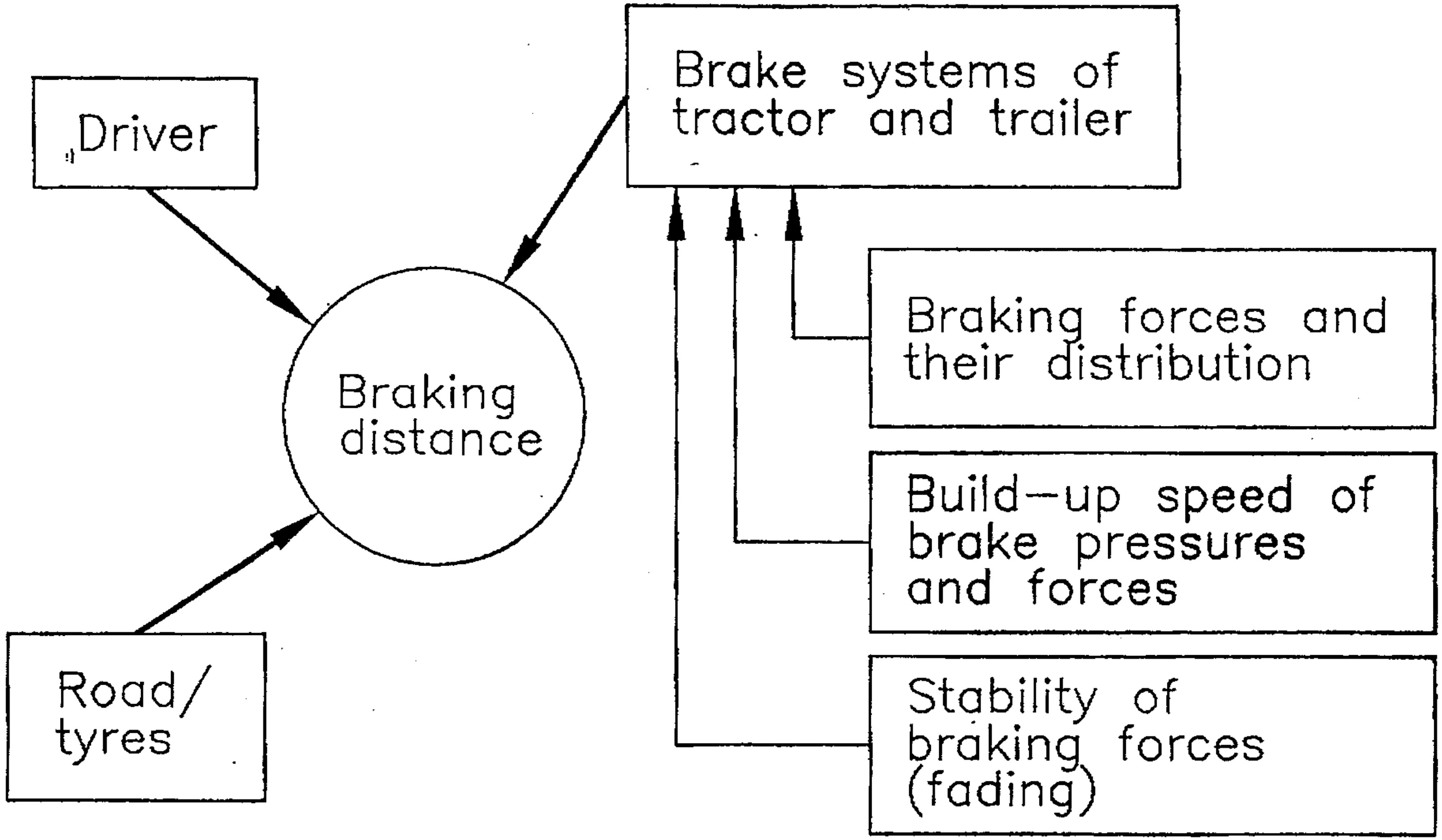
Development in engine output



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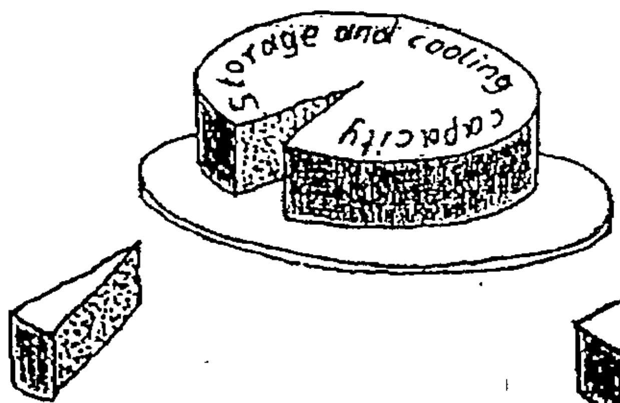
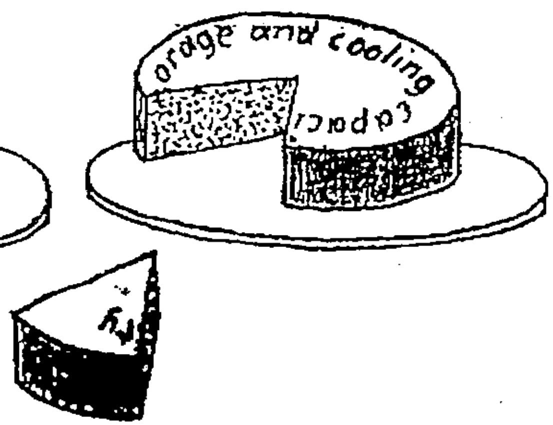
Factors affecting the braking distance

Minor braking



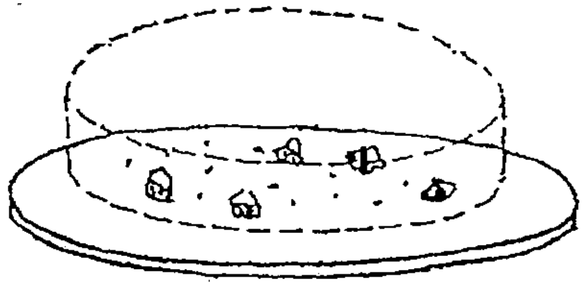
Braking energy incurred

Emergency braking



Braking energy incurred

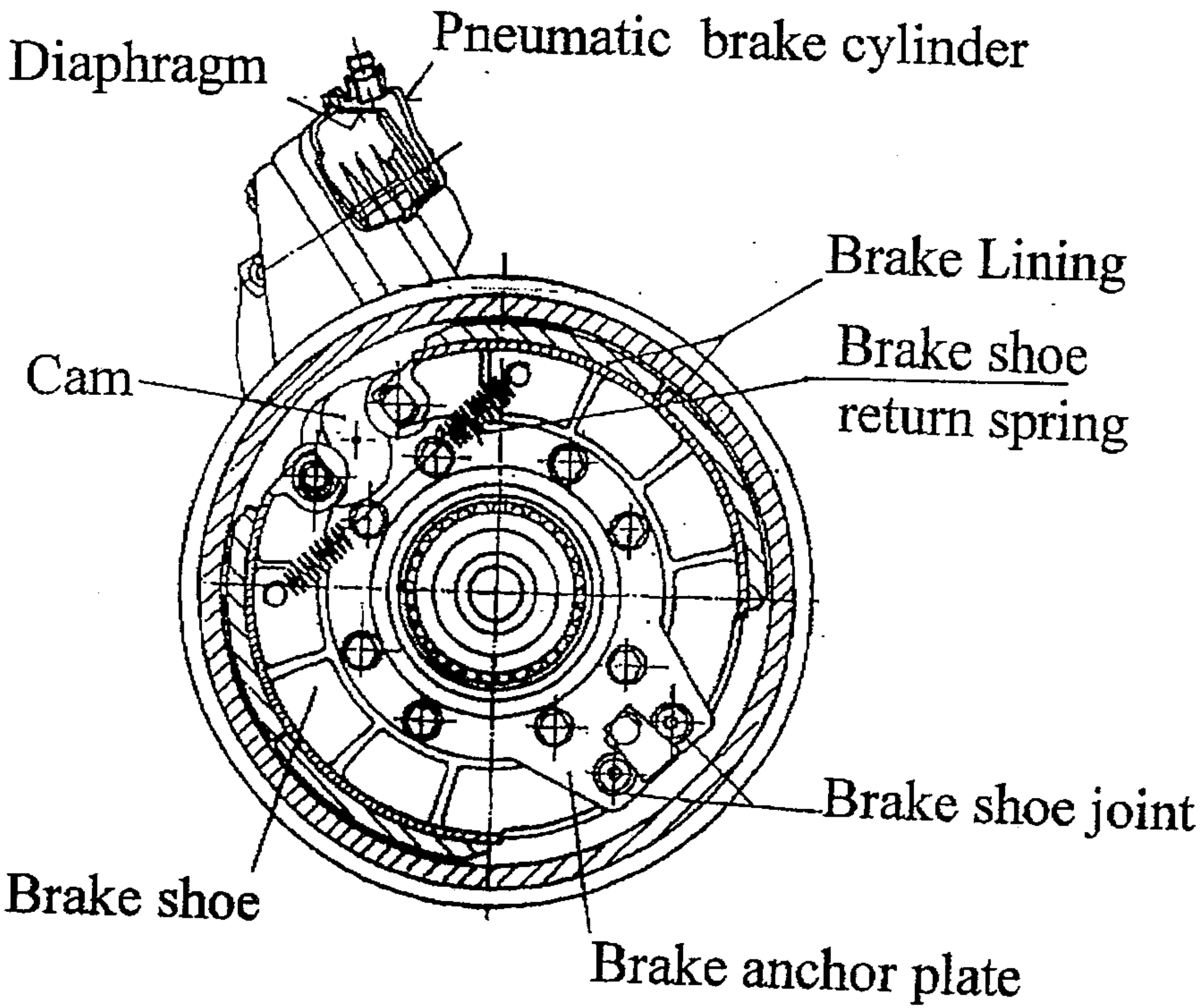
Downhill braking



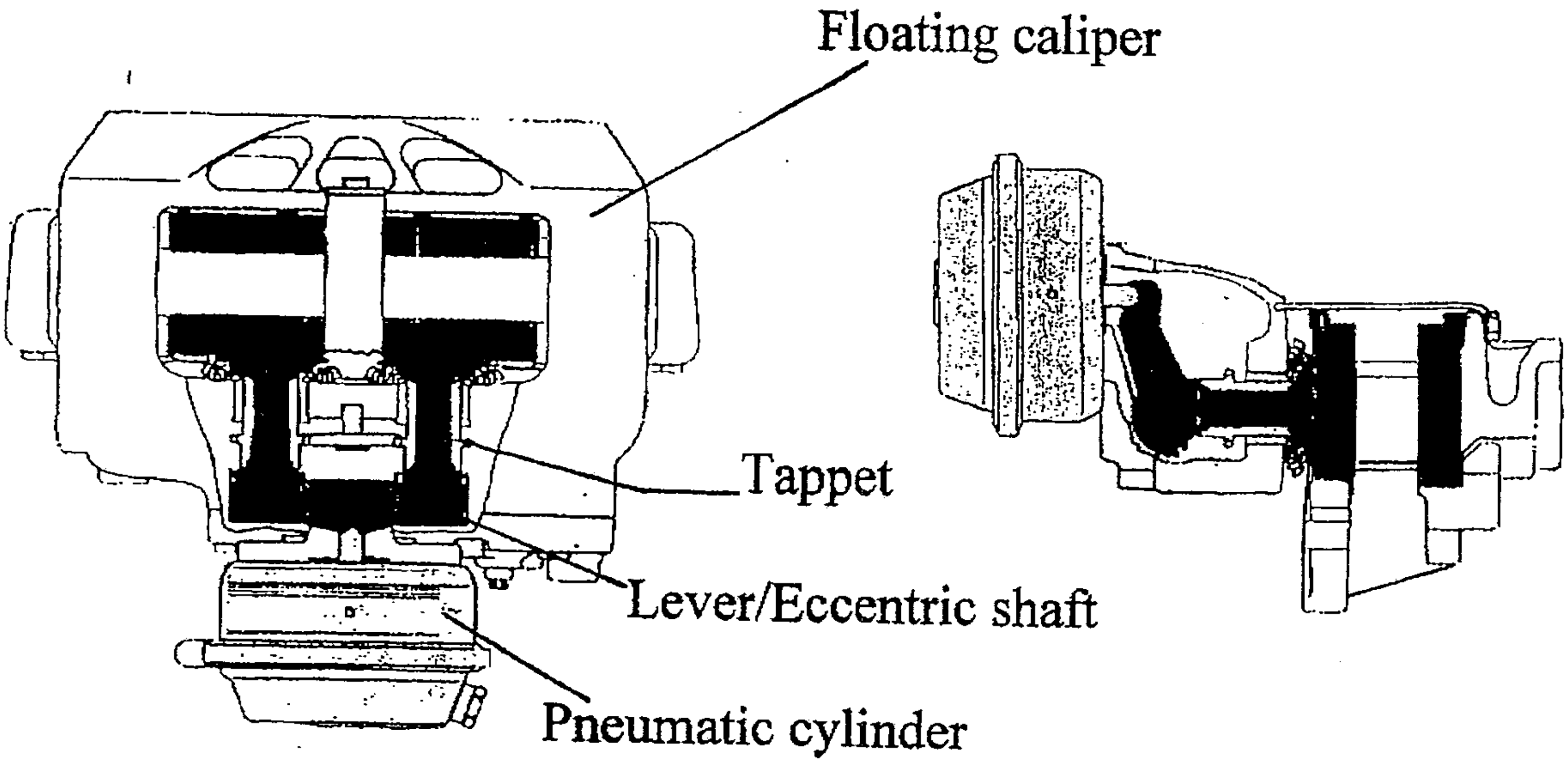
Braking energy incurred exhausts capacities after only a few minutes

7

Energy consumption of different types of braking

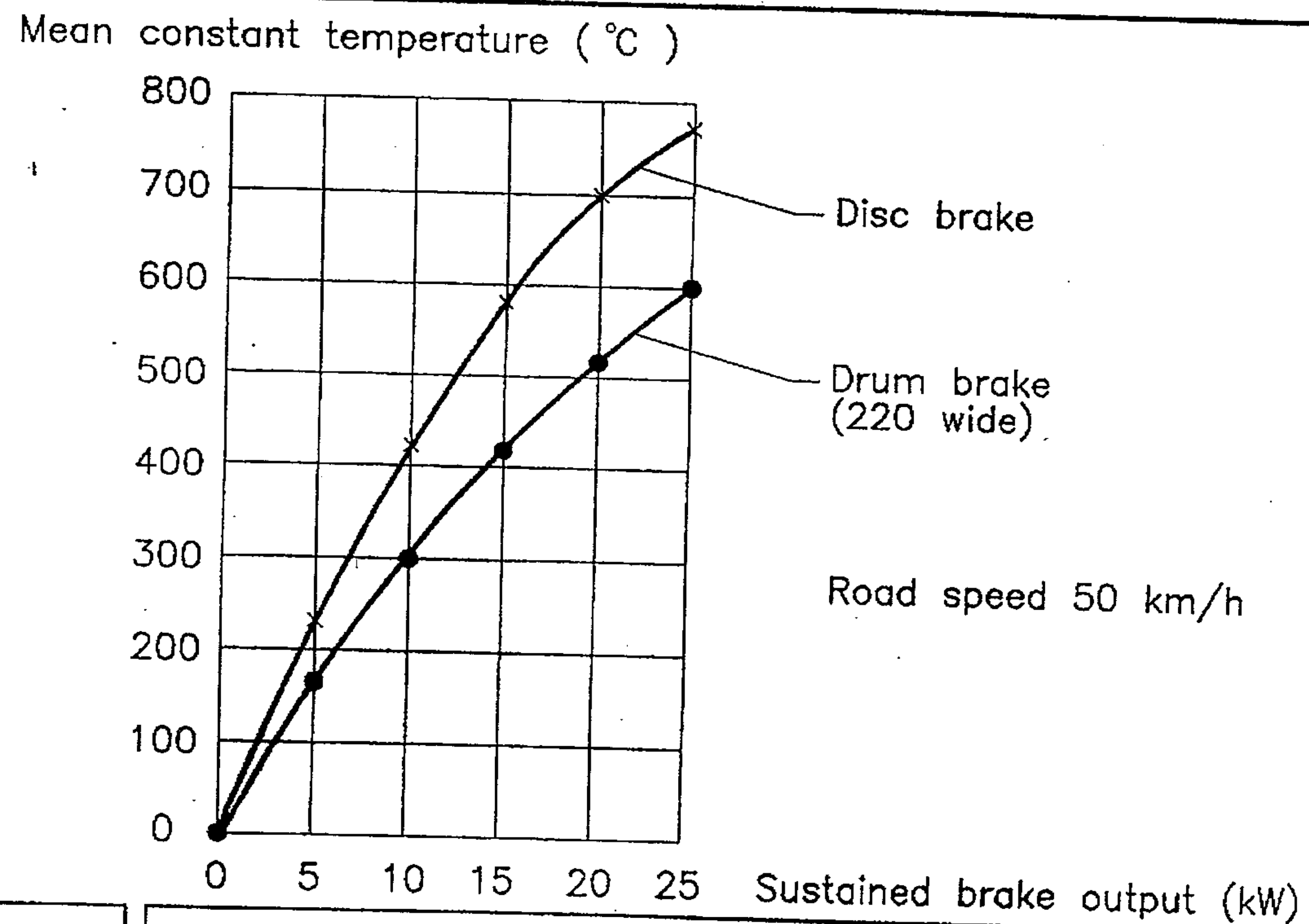

Diaphragm
Pneumatic brake cylinder
Brake Lining
Brake shoe
return spring
Cam
Brake shoe joint
Brake shoe
Brake anchor plate

Drum brake


Floating caliper
Tappet
Lever/Eccentric shaft
Pneumatic cylinder

9

Disc brake



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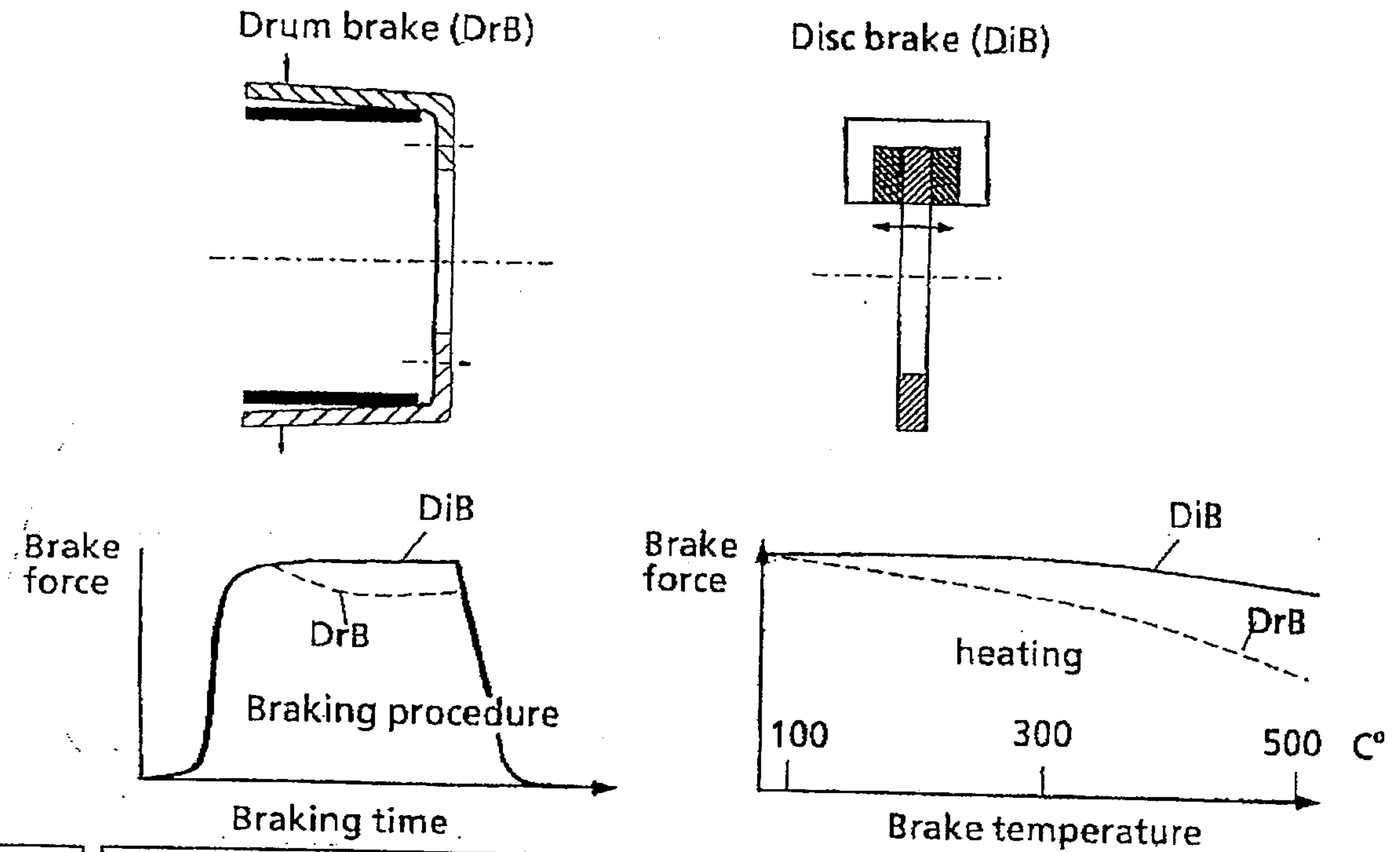
Brake temperatures at sustained output



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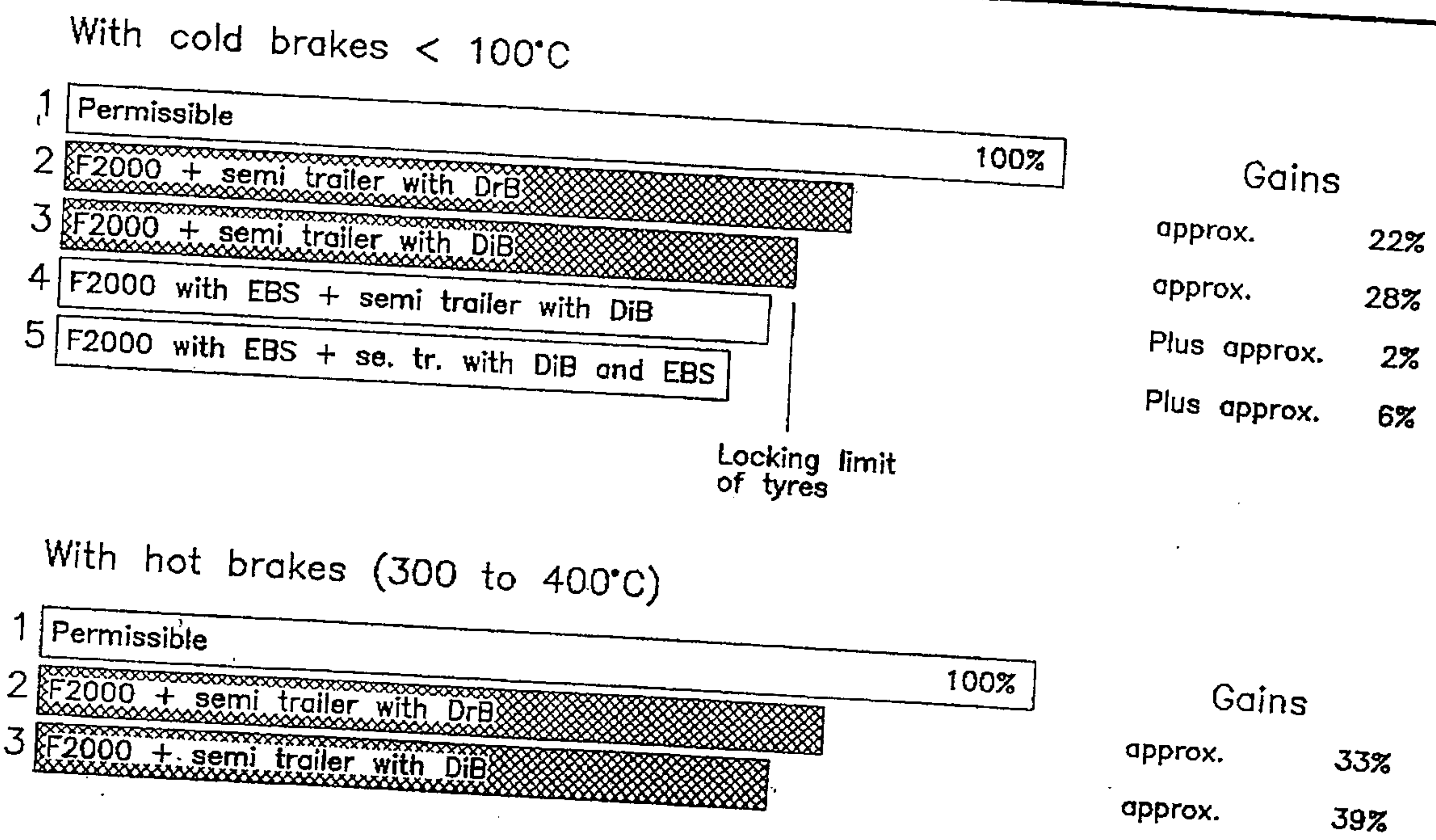
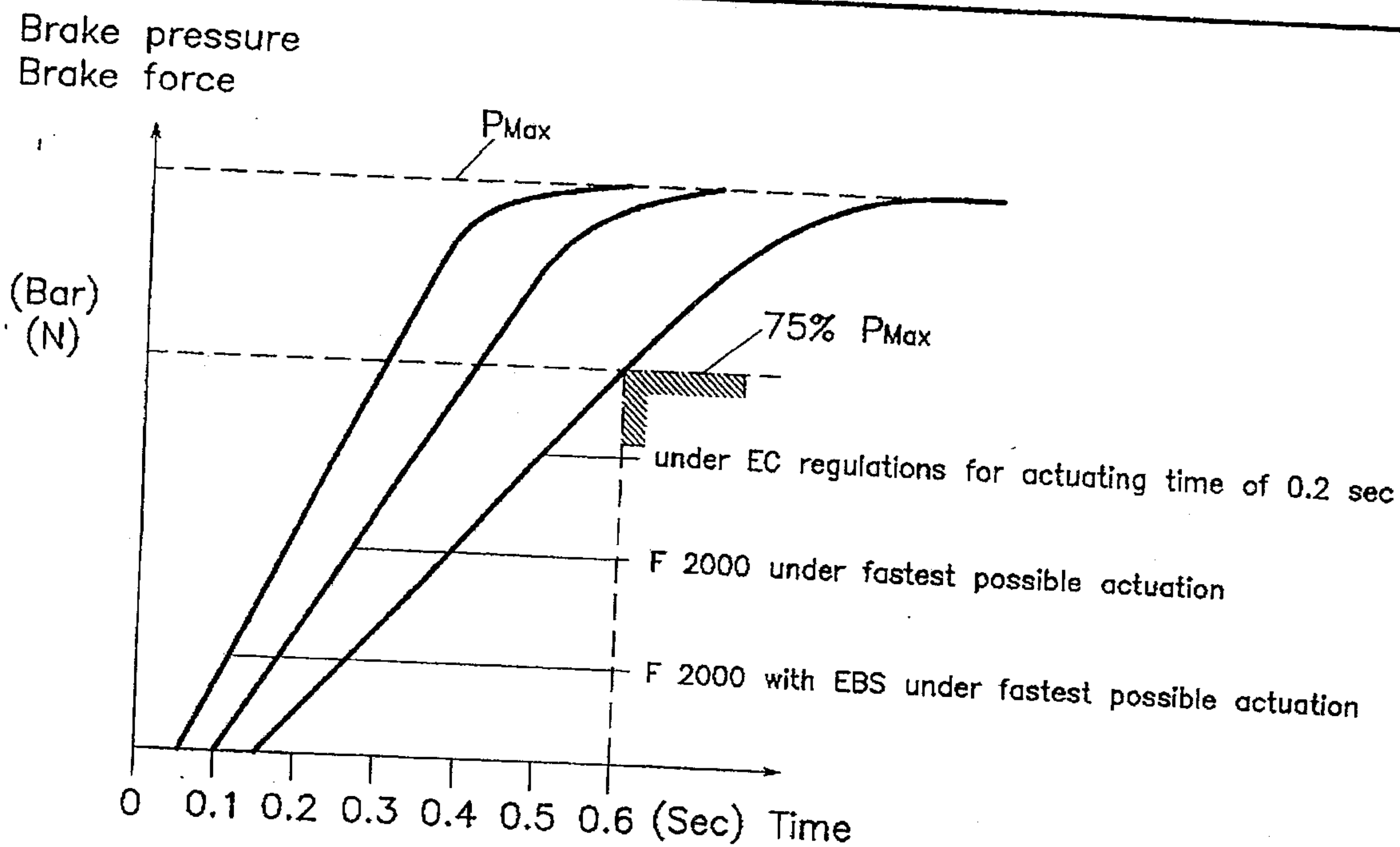
Brake force stability



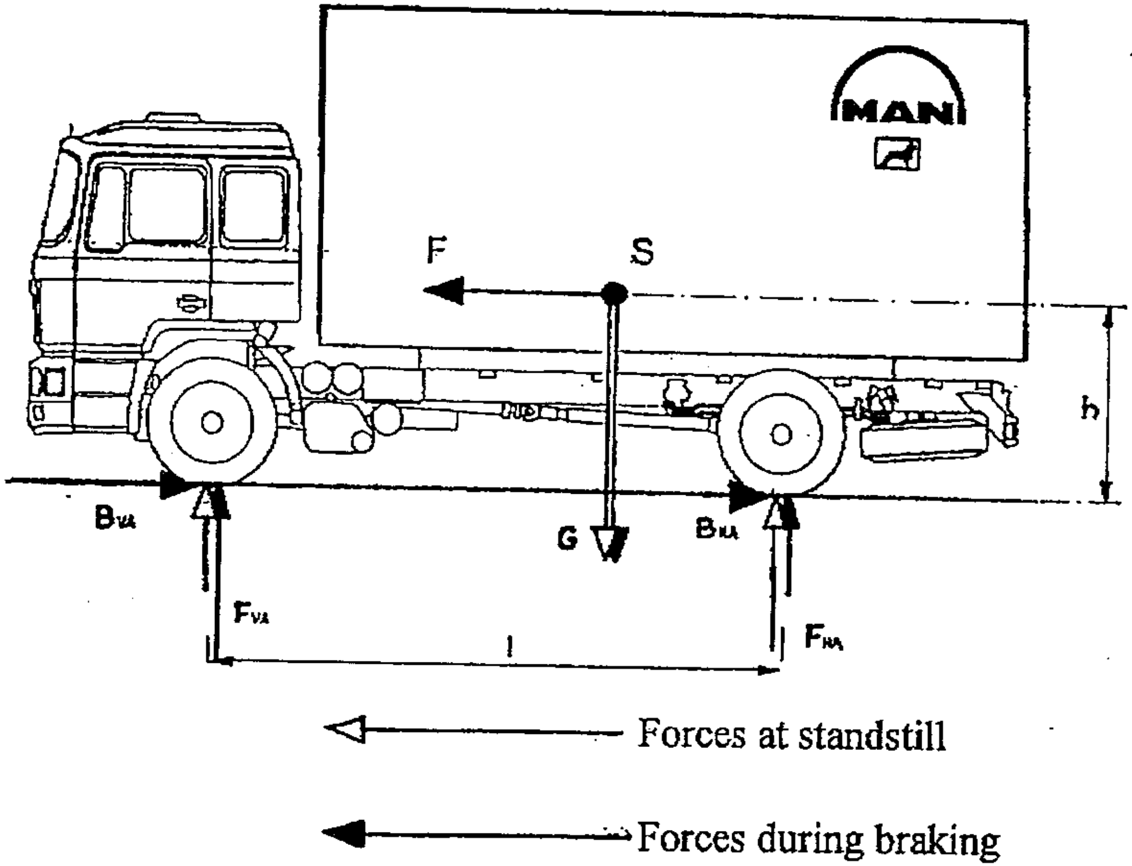
12

Gain in braking distance with F2000 from 80 km/h



13

Build-up speed of brake pressure
(Response time and pressure build-up time)



Axle load shift during braking:

$$\triangle G = (B_{VA} + B_{HA}) \cdot \frac{h}{l}$$

$$F = B_{VA} + B_{HA} = G.Z$$

$$B_{VA\,max} = F_{VA} \cdot \mu$$

$$B_{HA\,max} = F_{HA} \cdot \mu$$

Z: Deceleration

μ: Friction between tyres and road

Front axle load during braking up to 120 kN (12t)

Brake Force Distribution (F2000, 18t)