Antilock Braking Systems
Buckman Consulting Services, Inc.
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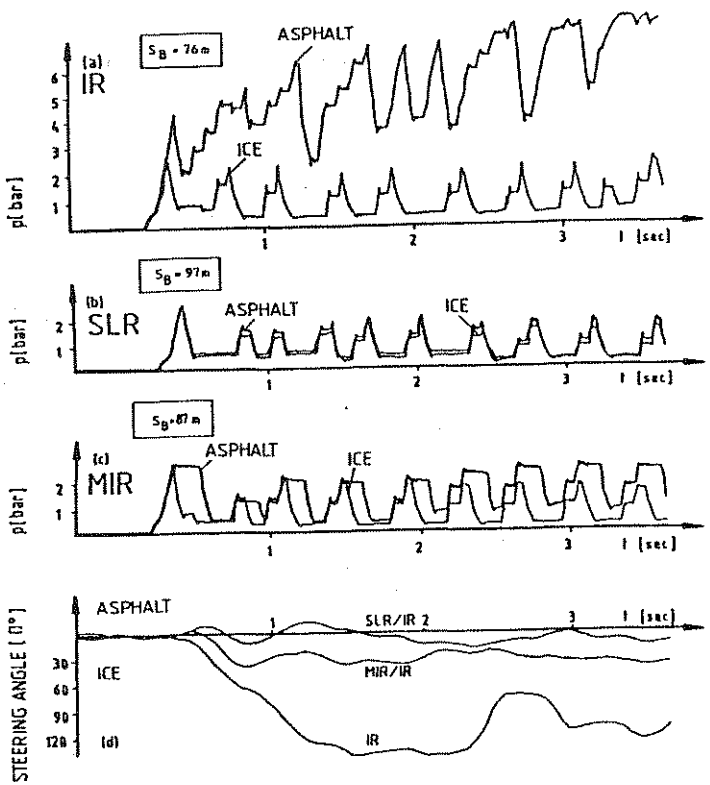
DISCLAIMER

ANTILOCK BRAKING SYSTEMS

ABS CONTROL SYSTEMS

- ALGORITHMS HAVE STEADILY EVOLVED SINCE THE 1970'S
  - FEATURES AND FUNCTIONS ADDED TO PROVEN PRINCIPLES
  - MERITOR WABCO ALGORITHM IS AN EVOLUTION OF AN 1981 PRODUCTION ALGORITHM
- REAR WHEELS: GENERALLY INDIVIDUAL WHEEL REGULATION (IR)
  - PROVIDES MAXIMUM RETARDATION
  - MAINTAINS MAXIMUM STABILITY
- FRONT WHEELS: GENERALLY MODIFIED INDIVIDUAL WHEEL REGULATION (MIR)
  - REDUCES VEHICLE YAW MOMENT ON SPLIT COEFFICIENT SURFACES
  - SIGNIFICANTLY BETTER STOPPING DISTANCES ON SLIT CO SURFACES THAN SELECT LOW SYSTEMS USED IN 1970'S

ANTILOCK BRAKING SYSTEMS



COMPARISION OF CONTROL PHILOSOPHIES
COMPARATIVE STEERING AND BRAKING
16 t SHORT - WHEELBASE BUS
INITIAL SPEED : 80 km/ h
SURFACE : DRY ASPHALT/ICE

COMPARISON OF CONTROL PHILOSOPHIES

- **TEST CONDITIONS:**
  - 16 TON, SHORT WHEELBASE BUS
  - 80 KM/HR STOPS ON SPLIT CO SURFACE
- **MEASUREMENTS:**
  - STEERING WHEEL ROTATIONAL DEVIATION INDICATES RELATIVE DEGREE OF BRAKE PULL
  - UPPER TRACES CHAMBER PRESSURES ON EACH SIDE – INDICATES RELATIVE RETARDATION
- **RESULTS:**
  - IR PROVIDES BEST BRAKING HOWEVER WORST BRAKE PULL (APPROX 120 DEGREES)
  - SLR PROVIDES LEAST BRAKE PULL HOWEVER LEAST BRAKING
  - MODIFIED INDIVIDUAL REGULATION (MIR) PROVIDES BEST COMPROMISE

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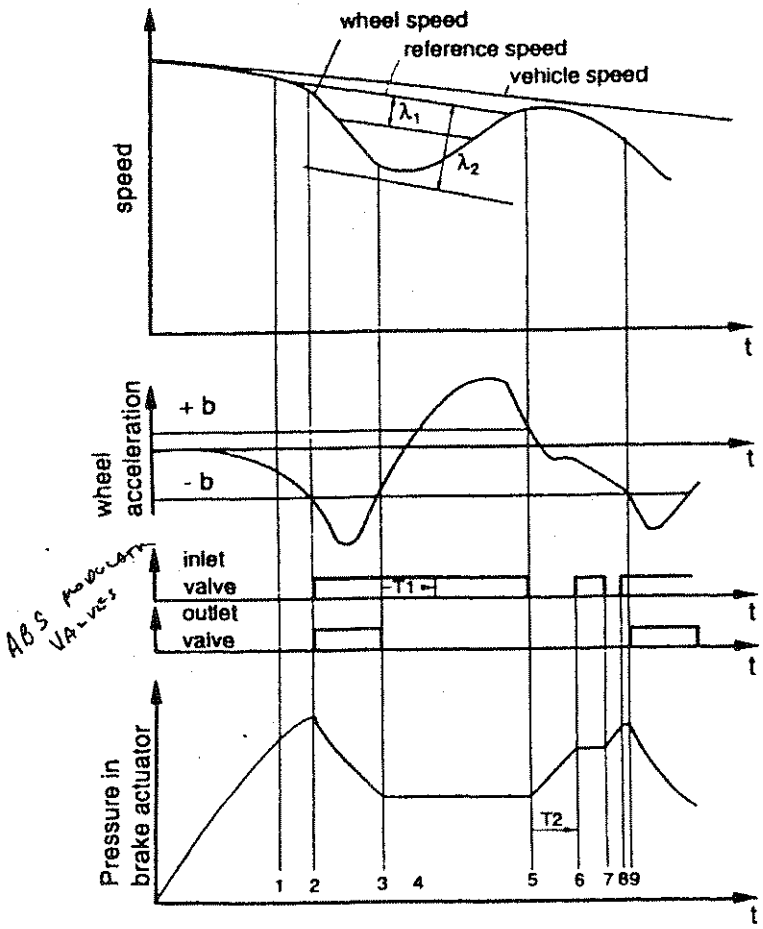
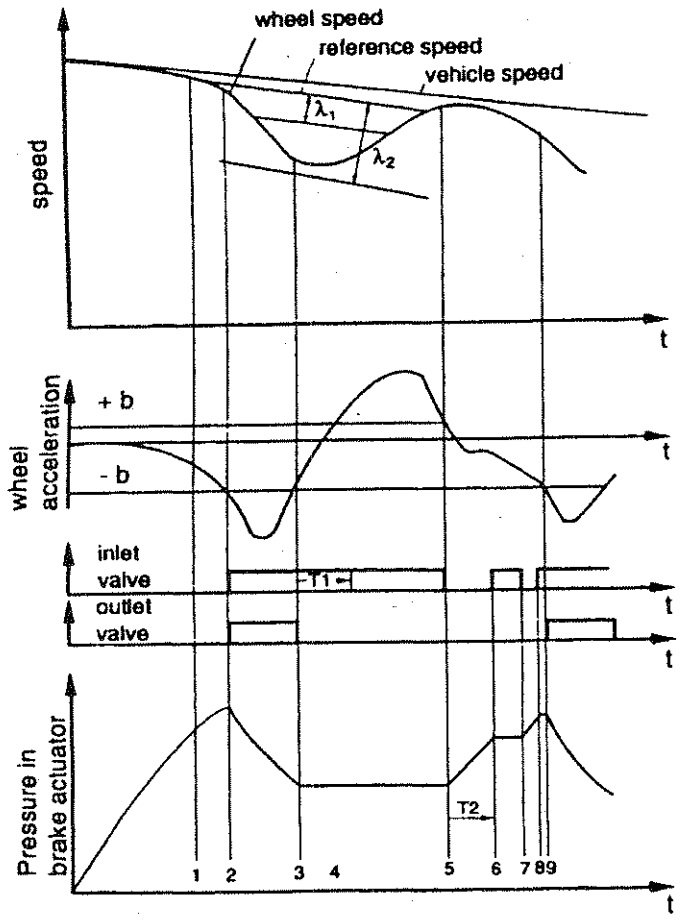


MERITOR WABCO CONTROL PHILOSOPHY

POINT 1:

- WHEEL DECELERATION EXCEEDS PHYSICAL LIMIT OF VEH DECELERATION
- REFERENCE SPEED AND WHEEL SPEED DIVERGE
- REFERENCE SPEED BASED ON SPEEDS OF WHEELS OF A DIAGONAL

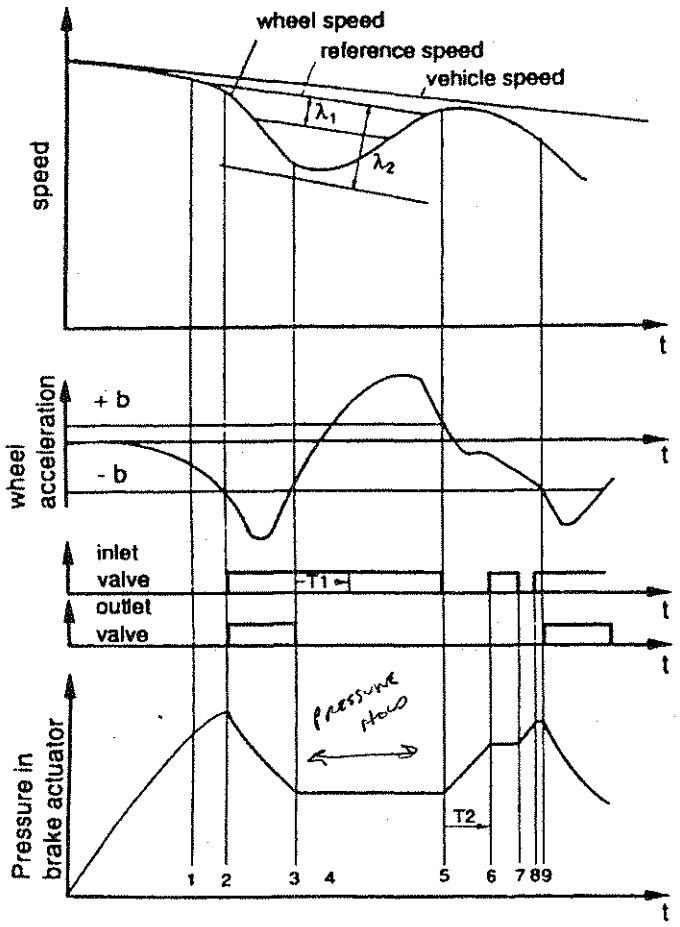
ANTILOCK BRAKING SYSTEMS



MW CONTROL PHILOSOPHY

POINT 2

- WHEEL DECELERATION EXCEEDS –b THRESHOLD
- WHEEL MOVES INTO UNSTABLE REGION OF SLIP CURVE
  - WHEEL HAS REACHED ITS MAX BRAKING FORCE
  - FURTHER INCREASE IN TORQUE DRIVES WHEEL INTO DEEPER SLIP
- SLIP IS CALCULATED FROM ACTUAL WHEEL SPEED AND CORRESPONDING REF SPEED
- ECU SIGNALS MODULATOR TO CLOSE INLET & OPEN OUTLET



MW CONTROL PHILOSOPHY

POINT 3:

- DECELERATION SIGNAL CROSSES –b THRESHOLD
- PRESSURE IS HELD FOR SET TIME (T1)
- NORMALLY WHEEL ACCELERATION WILL EXCEED +b WITHIN T1
- IF +b THRESHOLD SIGNAL IS NOT GENERATED IN T1, THEN BRAKE PRESSURE IS FURTHER DECREASED BY SLIP SIGNAL LAMBDA 1. DURING THIS CONTROL PHASE THE HIGHER SLIP THRESHOLD LAMBDA 2 IS NOT REACHED.

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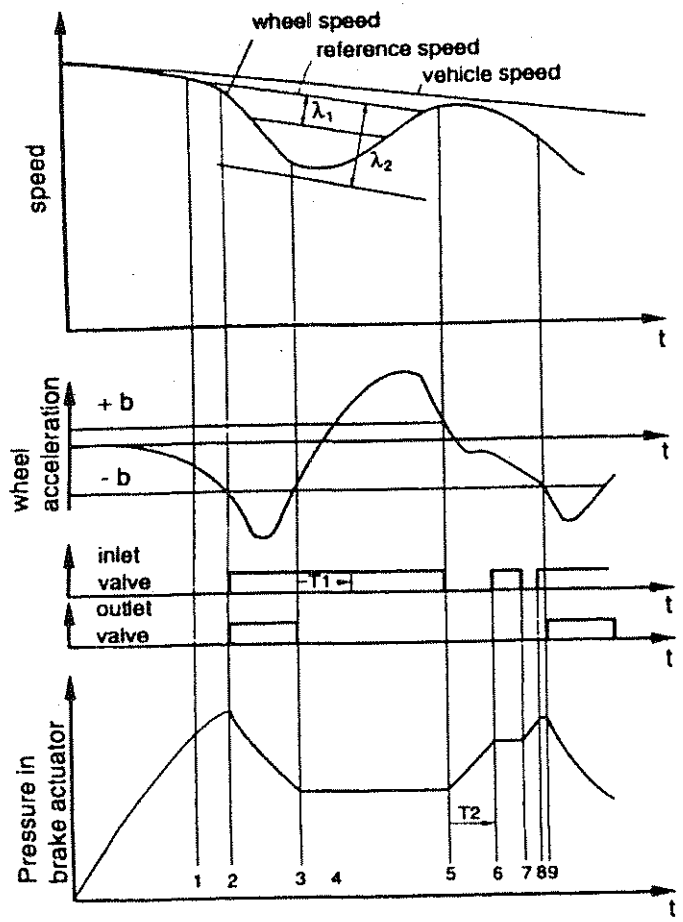
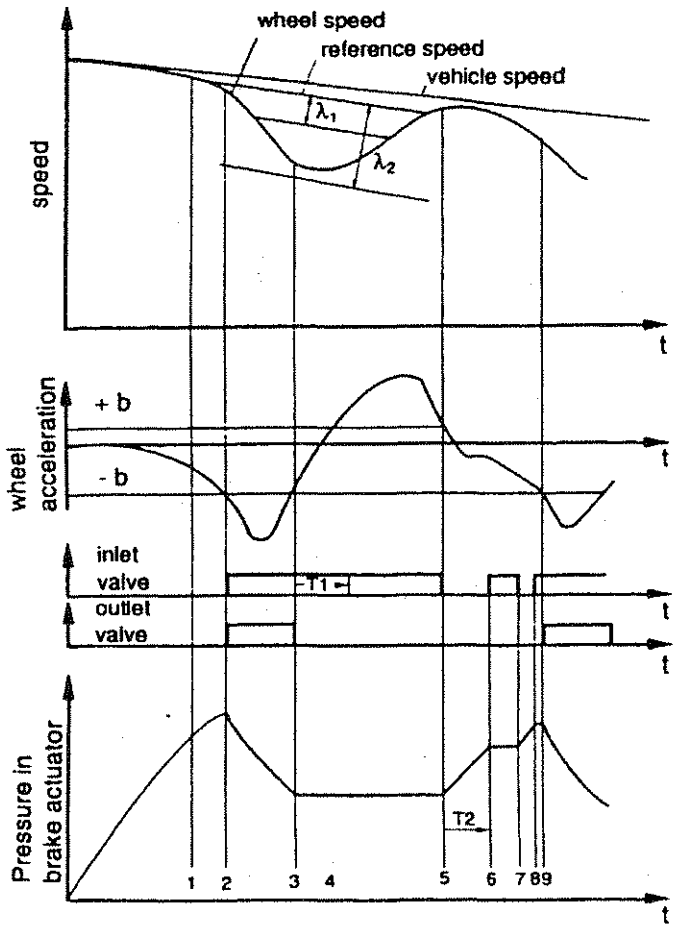


MW CONTROL PHILOSOPHY

POINT 5:

- WHEEL DECELERATION FALLS TO +b THRESHOLD
- WHEEL IN STABLE ZONE OF MU-SLIP CURVE
- BRAKE PRESSURE RAPIDLY APPLIED FOR TIME T2 TO OVERCOME BRAKE HYSTERESIS
- T2 IS FIXED FOR FIRST CYCLE - RECALCULATED THEREAFTER



CONTROL PHILOSOPHY (continued)

POINT 6, 7, 8:

- PRESSURE IS INCREASED BY "PULSES" OF ALTERNATING PERIODS OF PRESSURE HOLD AND INCREASE

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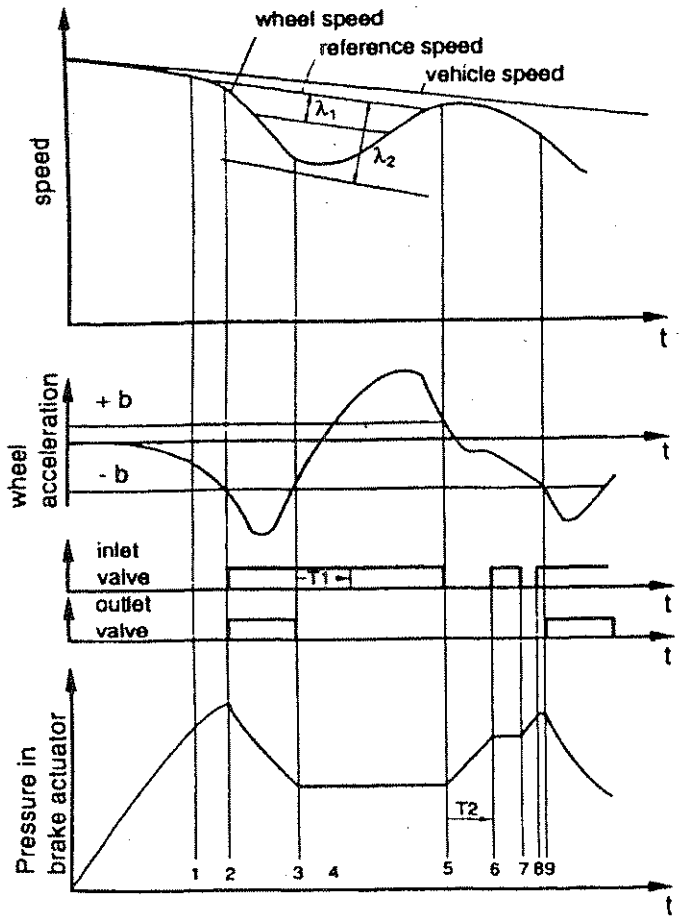

CONTROL PHILOSOPHY (continued)

- ***ABS CONTROL LOGIC IS NOT FIXED.***
  - ADAPTABLE TO DYNAMIC BEHAVIOR OF WHEEL ON DIFFERENT ROAD TO TIRE FRICTION COEFFICIENTS
  - NUMBER OF CONTROL CYCLES DEPENDENT UPON MANY FACTORS
- ***CYCLE RATE LIMITED BY WHEEL ROLL-UP AND/OR BRAKE CHAMBER AIR EXHAUST RATE***
  - TYPICALLY 3-5 CYCLES/SECOND
    Function of How Fast Can You Get Air In, Out, & Both In Chamber
  - SURFACES LIKE WET ICE ARE LESS

ANTILOCK BRAKE SYSTEMS

ALGORITHM IS MORE COMPLICATED THAN BASIC PHILOSOPHY:

- *BRAKE CHARACTERISTICS*
  - I.E. BRAKE INDUCED VIBRATIONS FROM OVERLY AGGRESSIVE LININGS AND HIGH BRAKE POWER
- *RANGE OF BRAKING PRESSURES (LESS THAN 1% OF BRAKE APPLICATIONS ARE FULL PRESSURE)*
- *IMPACT LOADS, WHEEL LOADING, BRAKE SYSTEM RESPONSE, SUSPENSIONS, VEHICLE CONFIGURATIONS, ETC.*
  - I.E. FRONT AXLE MIR AGGRESSIVENESS DETERMINED BY SHORT WHEELBASE VEHICLE RESPONSE
- *ALGORITHM MUST ACCOMMODATE:*
  - DIFFERENT SIZE TIRES ON THE VEHICLE'S AXLES
  - ENGINE BRAKES OR RETARDERS ~ ABS DISENGAGES RETARDER
  - SPECIAL OFF-ROAD OPERATIONAL FACTORS

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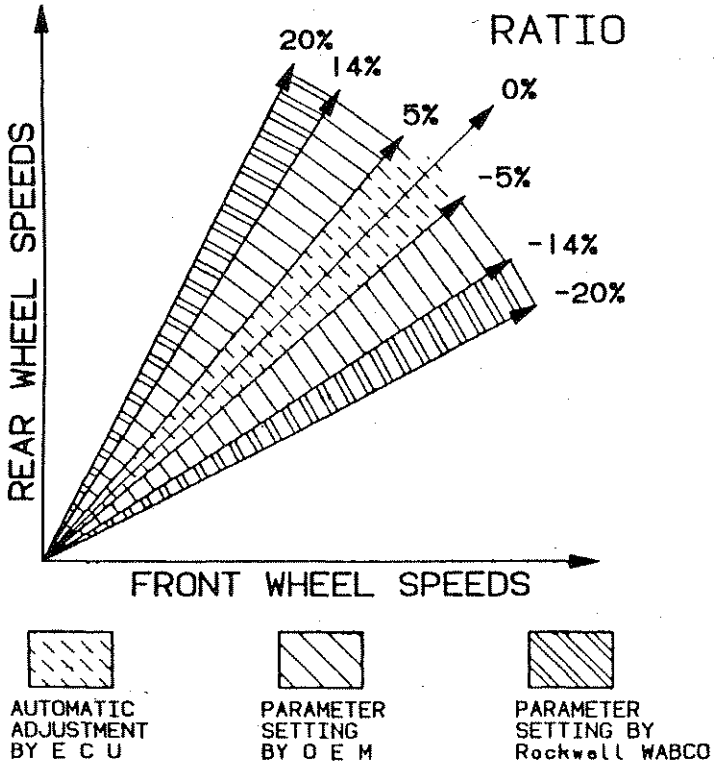

AUTOMATIC ADJUSTMENT BY E C U

BASIC CHECK OF RATIO	12 SECONDS
SAFETY CHECK OF RATIO	16 SECONDS

FRONT TO REAR TIRE SIZE ACCOMMODATION

- ECU CAN AUTOMATICALLY ACCOMMODATE APPROX +/- 5% Rolling Radius
- ECU CAN HAVE PARAMETER SETTING TO ACCOMMODATE APPROX =/- 14%
- ECU MANUFACTURER CAN ADJUST PARAMETERS TO ACCOMMODATE +/- 20%