David's Automotive Study Binder

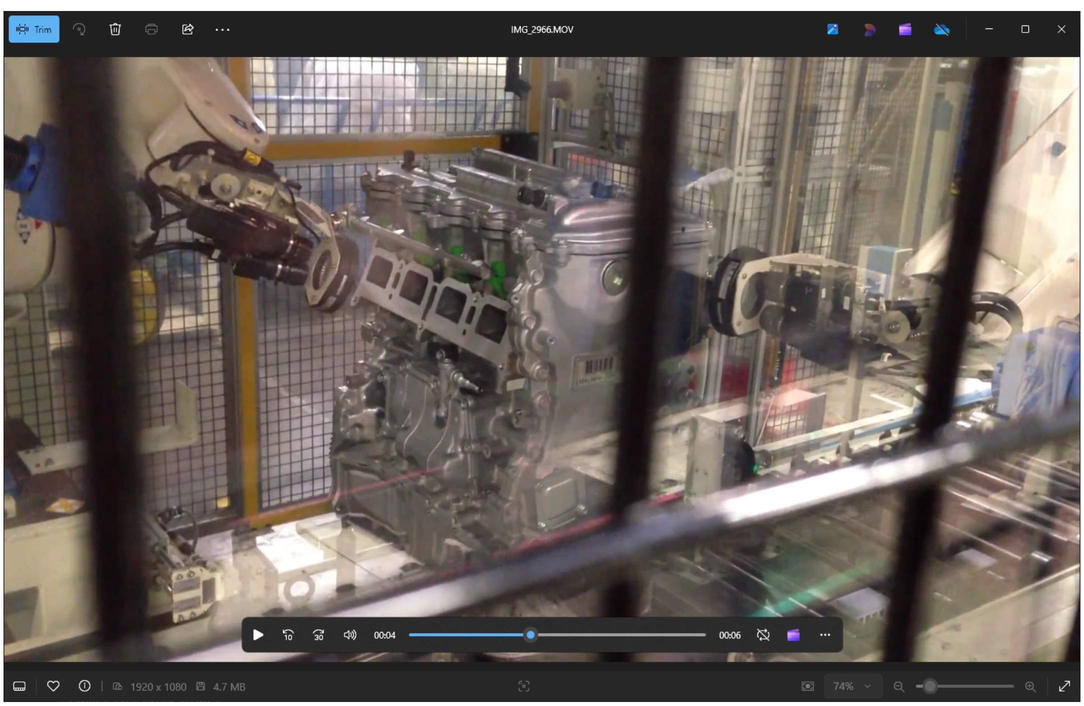
A scan of my notes from a self-guided study, during summer of my internship with Toyota Motor Manufacturing in Georgetown Kentucky, in 2009.

This binder is recommended as a *survey of topics relevant to automotive engineering,* for learners who wish to gain a systems-level awareness of elements inside of a modern automobile design. Perhaps 10% of the topics details are no longer relevant for the latest vehicles (circa 2020), however these technologies still formed the groundwork for our modern designs & methods.

I have also included a copy of my internship evaluation, for context. The evaluation of my performance is not so relevant to the reader. However it is a special opportunity to see how interns and engineers' work is evaluated in the workplace, by a world class company at the individual level.

There is nothing extraordinary about this document except for one thing, perhaps. It is becoming extremely rare for the Gen-z and alpha generations to find real life, tangible examples of the development path of a modern professional in any space, as most records are now digitized and devoid of the context and high-resolution authenticity. Alternatively, records which do hold finely-embedded authenticity seem to come only from the last century. In 2009 this document was a study guide, in 2019 it was reference material, and in 2029 perhaps it can be called art.   I hope some people can gain value and benefit from this.

-David Malawey, Feb 14, 2025



one of the extremely scarce photos I have from the Georgetown plant, TMMK (photography not allowed)

PDF REVISION 2025.02.14, 68 PAGES.   To upload at qr.net/openmeproject

Blue figures indicate wall thickness in inches

ANSI PIPE SCHEDULES

Black figures indicate weight per foot in pounds

PIPE SIZE	O.D. in inches	5	10	20	30	40	STD.	60	80	XH	100	120	140	160	XXH
1/8	.405	.035 .138	.049 .186			.068 .245	.068 .245		.095 .315	.095 .315					
1/4	.540	.049 .257	.065 .330			.088 .425	.088 .425		.119 .535	.119 .535					
3/8	.675	.049 .328	.065 .424			.091 .568	.091 .568		.126 .739	.126 .739					
1/2	.840	.065 .538	.083 .671			.109 .851	.109 .851		.147 1.088	.147 1.088				.187 1.304	.294 1.714
3/4	1.050	.065 .684	.083 .857			.113 1.131	.113 1.131		.154 1.474	.154 1.474				.218 1.937	.308 2.441
1	1.315	.065 .868	.109 1.404			.133 1.679	.133 1.679		.179 2.172	.179 2.172				.250 2.844	.358 3.659
1-1/4	1.660	.065 1.107	.109 1.806			.140 2.273	.140 2.273		.191 2.997	.191 2.997				.250 3.765	.382 5.214
1-1/2	1.900	.065 1.274	.109 2.085			.145 2.718	.145 2.718		.200 3.631	.200 3.631				.281 4.859	.400 6.408
2	2.375	.065 1.604	.109 2.638			.154 3.653	.154 3.653		.218 5.022	.218 5.022				.343 7.444	.436 9.029
2-1/2	2.875	.083 2.475	.120 3.531			.203 5.793	.203 5.793		.276 7.661	.276 7.661				.375 10.010	.552 13.700
3	3.500	.083 3.029	.120 4.332			.216 7.576	.216 7.576		.300 10.250	.300 10.250				.437 14.320	.600 18.580
3-1/2	4.0	.083 3.472	.120 4.973			.226 9.109	.226 9.109		.318 12.510	.318 12.510					.636 22.850
4	4.5	.083 3.915	.120 5.613			.237 10.790	.237 10.790	.281 12.660	.337 14.980	.337 14.980		.437 19.010		.531 22.510	.674 27.540
4-1/2	5.0						.247 12.530			.355 17.610					.710 32.530
5	5.563	.109 6.349	.134 7.770			.258 14.620	.258 14.620		.375 20.780	.375 20.780		.500 27.040		.625 32.960	.750 38.550
6	6.625	.109 7.585	.134 9.289			.280 18.970	.280 18.970		.432 28.570	.432 28.570		.562 36.390		.718 45.300	.864 53.160
7	7.625						.301 23.570			.500 38.050					.875 63.080
8	8.625	.109 9.914	.148 13.400	.250 22.360	.277 24.700	.322 28.550	.322 28.550	.406 35.640	.500 43.390	.500 43.390	.593 50.870	.718 60.630	.812 67.760	.906 74.690	.875 72.420
9	9.625						.342 33.900			.500 48.720					
10	10.75	.134 15.190	.165 18.700	.250 28.040	.307 34.240	.365 40.480	.365 40.480	.500 54.740	.593 64.330	.500 54.740	.718 76.930	.843 89.200	1.000 104.100	1.125 115.700	
11	11.75						.375 45.550			.500 60.070					
12	12.75	.165 22.180	.180 24.200	.250 33.380	.330 43.770	.406 53.530	.375 49.560	.562 73.160	.687 88.510	.500 65.420	.843 107.200	1.000 125.500	1.125 139.700	1.312 160.300	
14	14.0		.250 36.710	.312 45.680	.375 54.570	.437 63.370	.375 54.570	.593 84.910	.750 106.100	.500 72.090	.937 130.700	1.093 150.700	1.250 170.200	1.406 189.100	
16	16.0		.250 42.050	.312 52.360	.375 62.580	.500 82.770	.375 62.580	.656 107.500	.843 136.500	.500 82.770	1.031 164.800	1.218 192.300	1.437 223.500	1.593 245.100	
18	18.0		.250 47.390	.312 59.030	.437 82.060	.562 104.800	.375 70.590	.750 138.200	.937 170.800	.500 93.450	1.156 208.000	1.375 244.100	1.562 274.200	1.781 308.500	
20	20.0		.250 52.730	.375 78.600	.500 104.100	.593 122.900	.375 78.600	.812 166.400	1.031 208.900	.500 104.100	1.280 256.100	1.500 296.400	1.750 341.100	1.968 379.000	
22	22.0		.250 58.070	.375 86.610	.500 114.800		.375 86.610	.875 197.400	1.125 250.800	.500 114.800	1.375 302.900	1.625 353.600	1.875 403.000	2.125 451.100	
24	24.0		.250 63.410	.375 94.620	.562 140.800	.687 171.200	.375 94.620	.968 238.100	1.218 296.400	.500 125.500	1.531 367.400	1.812 429.400	2.062 483.100	2.343 541.900	
26	26.0		.312 85.600	.500 136.200			.375 102.600			.500 136.200					
28	28.0		.312 92.260	.500 146.800	.625 182.700		.375 110.600			.500 146.800					
30	30.0		.312 98.930	.500 157.500	.625 196.100		.375 118.600			.500 157.500					
32	32.0		.312 105.600	.500 168.200	.625 209.400	.688 230.100	.375 126.700			.500 168.200					
34	34.0		.344 123.700	.500 178.900	.625 222.800	.688 244.800	.375 134.700			.500 178.900					
36	36.0		.312 118.900	.500 189.600	.625 236.100	.750 282.300	.375 142.700			.500 189.600					
42	42.0						.375 166.700			.500 221.600					
48	48.0						.375 190.700			.500 253.600					

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References Section

printouts from 2009-2011 to accompany the notes content.

Airline Hydraulic's Main Page

Basic Symbols

Download Autocad symbols from the Autodesk website

Lines

-continuous line - flow line

-dashed line - pilot, drain pilot ≈ control

-envelope - long and short dashes around two or more component symbols.

Circular

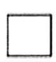
P Torque ⇒ pressure
pressure ⇒ torque

-large circle - pump, motor

-small circle - Measuring devices

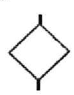
-semi-circle - rotary actuator

Square



-one square - pressure control function
-two or three adjacent squares - directional control

Diamond



-diamond - Fluid conditioner (filter, separator, lubricator, heat exchanger)

Miscellaneous Symbols

-Spring

-Flow Restriction

Triangle

▼ -solid - Direction of Hydraulic Fluid Flow

▽ -open - Direction of Pnematic flow

Pumps and Compressors

Fixed Displacement hydraulic pump

-unidirectional

~~-bidirectional~~

– bidirectional

Variable displacement hydraulic pump

-unidirectional

-bidirectional

Compressor

Motors

Fixed displacement hydraulic motor

-unidirectional

-bidirectional

Variable displacement hydraulic motor

-unidirectional

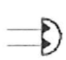
-bidirectional

Pneumatic motor

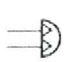
-unidirectional

-bidirectional

Rotary Actuator



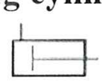
- hydraulic



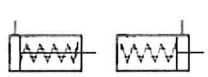
- pneumatic

Cylinders

Single acting cylinder

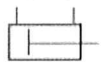


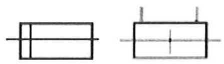
-returned by external force



-returned by spring or extended by spring force

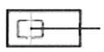
Double acting cylinders

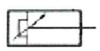

-single piston rod (fluid required to extend and retract)

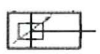

-double ended piston rod

Cylinders with cushions


- single fixed cushon

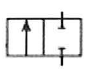

- double fixed cushion

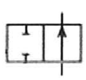

- single adjustable cushion


- double adjustable cushion

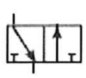
Directional Control Valves

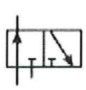
Directional control valve (2 ports / 2 positions)


-Normally closed directional control valve with 2 ports and 2 finite positions.


-Normally open directional control valve with 2 ports and 2 finite positions.

Directional control valve (3 ports / 2 positions)

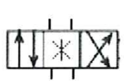

-Normally closed directional control valve with 3 ports and 2 finite positions.


-Normally open directional control valve with 3 ports and 2 finite positions.

Directional control valve (4 ports / 2 positions)


-directional control valve with 4 ports and 2 finite postions

Directional control valve (4 ports / 3 positions)

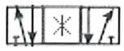

-directional control valve with 4 ports and 3 finite postions
*-(center position can have various flow paths)

Directional control valve (5 ports / 2 positions) Normally a pneumatic valve


-directional control valve with 5 ports and 2 finite postions

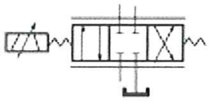
Directional control valve (5 ports / 3 positions) Normally a pneumatic valve

-directional control valve with 5 ports and 3 finite postions

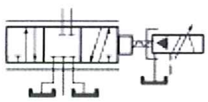


Proportional directional control valve
Electro-hydraulic servo valve

-The spool positions on these valves is variable allowing for variable flow conditions.



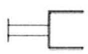
-single-stage **direct operation** unit which accepts an analog signal and provides a similar analog fluid power output



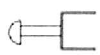
-two-stage with mechnical feedback **indirect pilot operation** unit which accepts an analog signal and provides a similar analog fluid power output

Control Methods

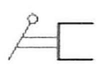
Manual Control



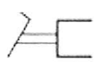
-general symbol (without showing the control type)



-pushbutton

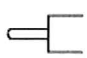


-lever

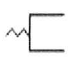


-foot pedal

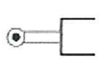
Mechanical Control



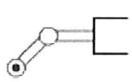
-plunger or tracer



-spring

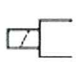


-roller



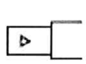
-roller(one direction only)

Electrical Control

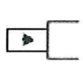


-Solenoid (the one winding)

Pilot Operation



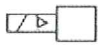
-pneumatic



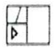
-hydraulic

Pilot operated two-stage valve

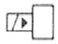
Solenoid



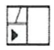
-Pneumatic: Sol first stage



-Pneumatic: Air pilot second stage



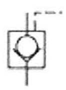
-Hydraulic: Sol first stage



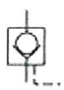
-Hydraulic: Hyd pilot second stage

Check valves, Shuttle valves, Rapid Exhaust valves

-check valve -free flow one direction, blocked flow in other direction

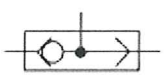


-pilot operated check valve, pilot to close



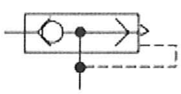
-pilot operated check valve, pilot to open

Shuttle valve



-to isolate one part of a system from an alternate part of circuit.

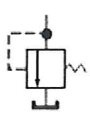
Rapid exhaust valve/Pneumatic



-installed close to an actuator for rapid movement of the actuator.

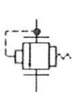
Pressure Control Valves

Pressure Relief Valve(safety valve) normally closed



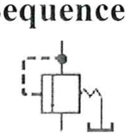
- line pressure is limited to the setting of the valve, secondary part is directed to tank.

Proportional Pressure Relief



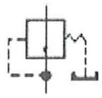
- line pressure is limited to and proportional to an electronic signal

Sequence Valve



- when the line pressure reaches the setting of the valve, valve opens permitting flow to the secondary port. The pilot must be externally drained to tank.

Pressure Reducing valve - pressure downstream of valve is limited to the setting of the valve



Flow Control Valves

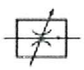
Throttle valve

 -adjustable output flow

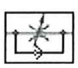
Flow Control valve

 -with fixed output (variations in inlet pressure do not affect rate of flow)

 -with fixed output and relief port to reservoir with relief for excess flow (variations in inlet pressure do not affect rate of flow)

 -with variable output

 -fixed orifice

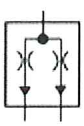
 -metered flow toward right free flow to left

 -pressure compensated flow control fixed output flow regardless of load

 -pressure and temperature compensated

 -with variable output and relief port to reservoir

Flow dividing valve

 -flow is divided equally to two outputs.

Shut-Off Valve

 -Simplified symbol

Accumulators

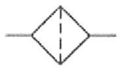
energy storage. held under pressure by external source (~~Weight~~ spring, raised weight, or compressed gas)

- helps avoid fluid hammer

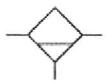
Filters, Water Traps, Lubricators and Miscellaneous

Apparatus

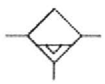
Filter or Strainer



Water Trap

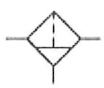


-with manual drain

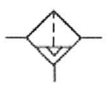


-with automatic drained

Filter with water trap

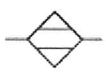


-with manual drain



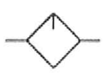
-automatic drain

Air Dryer



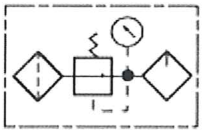
refrigerant, or chemical removal of water from compressed air line

Lubricator



-oil vapor is indected into air line

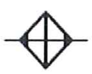
Conditioning unit



-compound symbol of filter, regulator, lubricator unit

-Simplified Symbol

Heat Exchangers



-air or water cooled unit designed to remove heat from oil returning to reservoir

C ST = centistrokes
or mm/sec^2.
it is kinematic viscosity, resistance to flow & shear by forces of gravity

VISCOSITY @ 100deg C		VISCOSITY @ 40deg C	
MOTOR OILS, HYDRAULIC OILS		ISO GRADE	
SAE GRADE RANGE (cST)		ISO GRADE RANGE (cST)	
5	3.80-*	32	28.8-35.2
10	4.10-*	46	41.4-50.6
20	5.60-9.29	68	61.2-74.8
30	9.30-12.49	100	90.0-110
40	12.50-16.29	150	135-165
50	16.30-21.89	220	198-242
60	21.90-26.09	320	288-352
80	7.0-11.00	460	414-506
90	13.50-23.99	680	612-748
140	24.00-40.99	1000	900-1100
250	41.00-UP	1500	1350-1650

Viscosities can be related horizontally only
Viscosities based on 96 VI single grade oils.
ISO are specified at 40 deg C
AGMA are specified at 40 deg C
SAE 75w, 80w, 85, 5w, & 10w
specified at low temperature.
Equivalent viscosities for 100 & 210 deg F are shown
SAE 90 to 250 and 20 to 50 specified at 100 deg C.

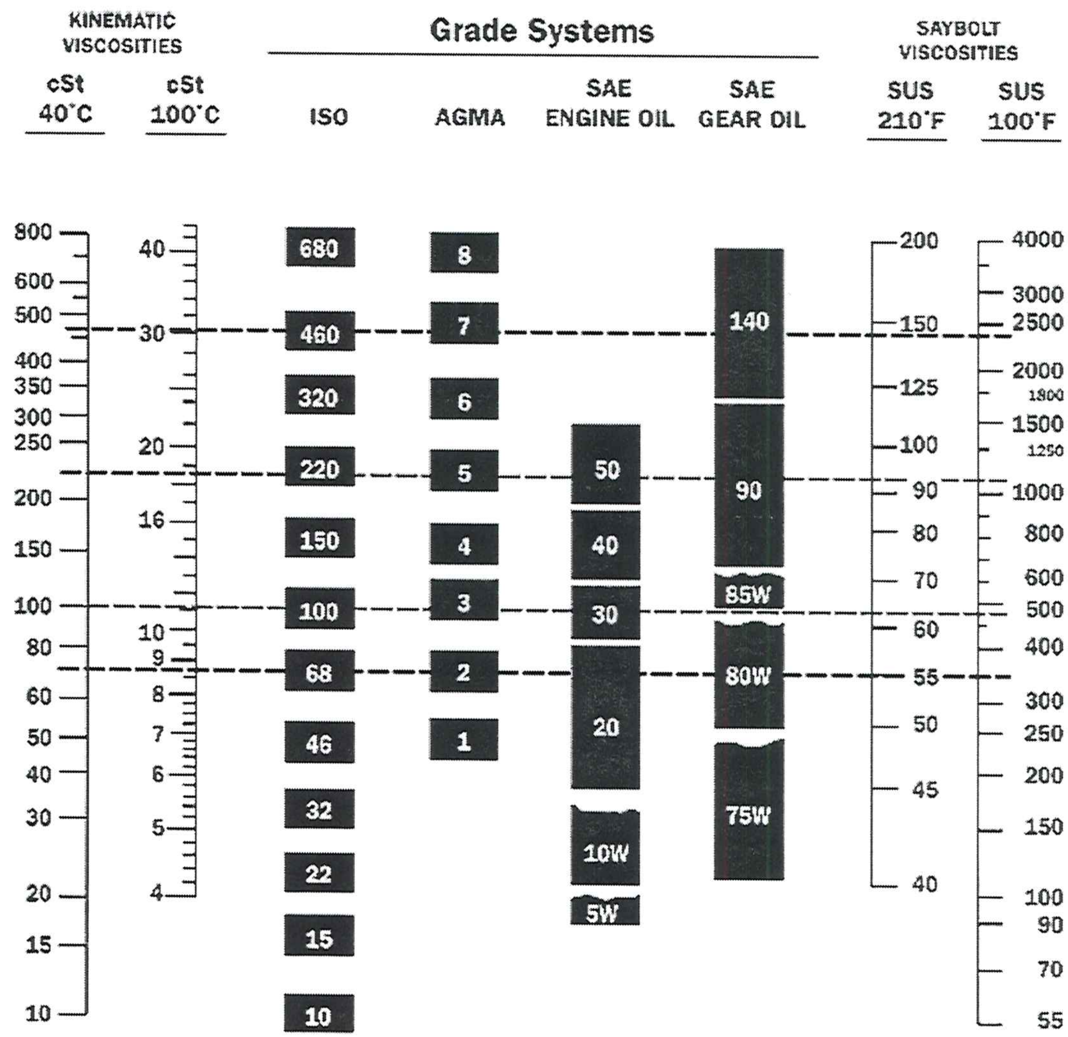
ISO VISCOSITY CLASSIFICATION SYSTEM

Many petroleum products are graded according to the ISO Viscosity Classification System, approved by the international standards organization (ISO). Each ISO viscosity grade number corresponds to the mid-point of a viscosity range expressed in centistokes(cSt) at 40 deg C. For example, a lubricant with an ISO grade of 32 has a

Rule of thumb: the comparable ISO grade of a given product whose viscosity in SUS at 100 deg F is known can be determined w/ the following conv. formula:

SUS @ 100°F / cSt @ 40°C $cSt = 0.226 \times SUS - (195/SUS)$

Motor Oil



Viscosities can be related horizontally only. For example, the following oils have similar viscosities: ISO 460, AGMA 7 and SAE GEAR OIL 140.

The viscosity/temperature relationships are based on 95 VI oils and are usable only for mono grade engine oils, gear oils and other 95 VI oils.

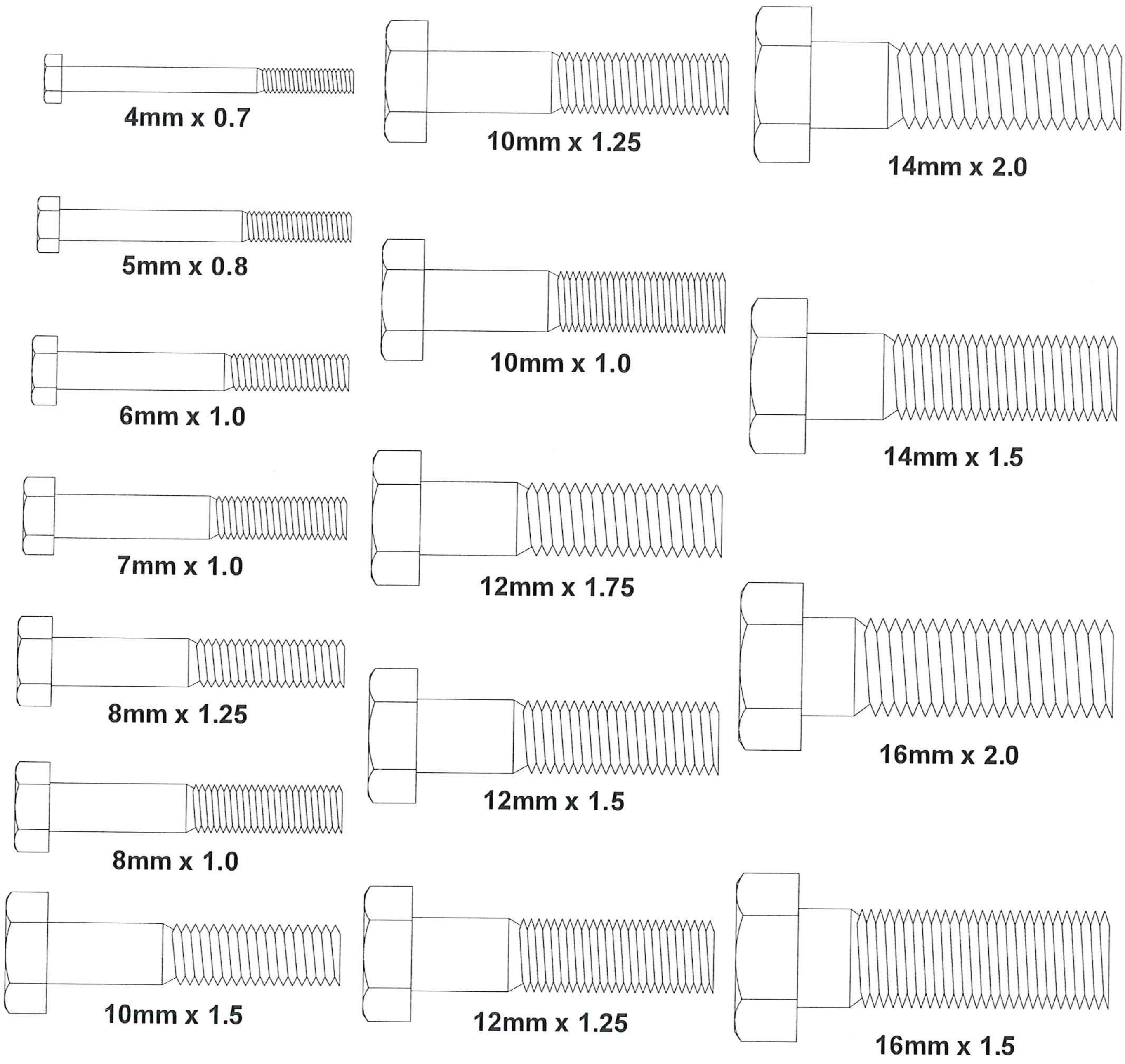
Crankcase oils and gear oils are based on 100°C viscosity. The "W" grades are classified on low temperature properties. ISO oils and AGMA grades are based on 40°C viscosity.

Standard Metric Hex Bolt Sizes and Thread Pitches

PRINTABLE FASTENER TOOLS SERIES

Bolt Depot™.com
fastener shopping made easy

(Note: Head sizes may differ from what is shows due to differences between metric standards)



Measure length from under the head to the end of the bolt.

mm 10 20 30 40 50 60 70 80 90 100

0 1 2 3 4 5 6 inches

Scale Check: After printing, measure ruler above to ensure correct scale

Paint - buffing/polishing

Foam polishing pads: active polishing action to remove minor surface imperfections, restores high gloss

buff out orange peel: wet or dry sand at 1000 to 800 grit, start with 1000 & see if you need more. Next, wetsand with 1500 grit or 2000 and then buff. Soapy water helps
- the darker the color, the worse the paint will show marks

buffing wheels - circle-sewn cotton wheels
- spiral sewn - surface imperfections deburring, & weld scale removal
- cusion sewn - Ideal for light cutting & polishing
- used on metal surfaces

polisher, variable speed.
- shaped like an angle-grinder
- can have 7" wheel, 0 -> 2,500 rpm motor

wool fast-change buffing pads, for paint
-

Paint

Acrylic - paint containing pigment suspended in an acrylic polymer emulsion.
- can be diluted with water, can be gloss or matte
- becomes water-resistant when dry
- uses
  - + 'latex' house paints
    - interior - combo of 'binder' and filler, pigment, water
    - + exterior - best 100% acrylic

Binder:
- creates adhesion in paint.
- is the body of the paint mostly
- sometimes ACRYLIC, VINYL, PVA
  - PVA polyvinyl acetate, a rubbery synthetic polymer
    - * used in wood glue,

Enamel: paint that air dries to a hard, usually glossy finish

Lacquer: in general, a clear varnish that dries by solvent evaporation & often a curing process as well producing a hard, durable finish
- ultra matte to high gloss
- can be further polished
- polymers dissolved in VOC's OR acrylic compounds dissolved in lacquer thinner
  - lacquer thinner is a mixture of solvents
  - called shellac. not as ~~strong~~ durable as lacquer

Adjustable cam gears -

Move cam angle on timing belt without changing cams

- increase hp
- Use on milled, forced induction engines
- usually aluminum

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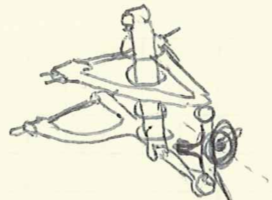
Suspension

suspension types / components

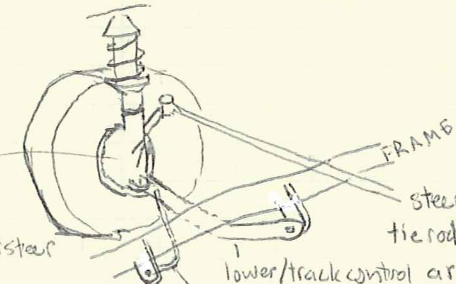
double wishbone: shock & spring integrated with a-arms / control arms



- SLA short long arms, have uneven length, common on medium-large cars for front suspension
- usually induces negative camber as suspension jounces (rises)
- body roll produces positive camber on outside wheel in turns

- used on older cars and RWD cars more often
- usually considered to have superior dynamics, load handling, etc.

Macpherson strut: system which uses the axis of a telescopic damper as the upper steering pivot

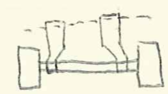


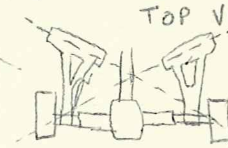
- called Chapman struts when used on rear of a vehicle
- wheels tend to lean with the body & cause understeer
- useful on unibody cars for strong top mount & more room for FWD transaxle with no upper control arm.

- coil over: coil spring over strut, a basic component of macpherson strut
- spring rate: $F = -kx$ F: force k = spring rate x = displacement of spring from equilibrium

Torsion bars: advantages are durability ride height adjustable easily, takes up less room from the interior volume of a vehicle than coil springs
- disadvantage: usually cannot provide progressive spring rate
- are sometimes used with a motor to adjust ride height or automatic levelling

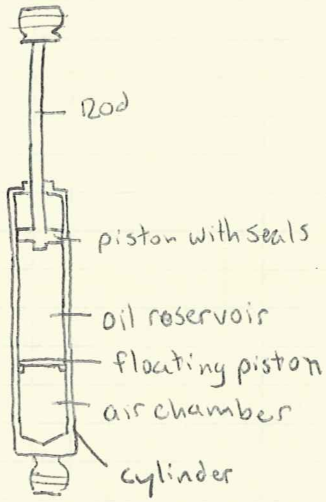
- trailing arm: suspension arm that connects behind the axle.
  - often used on rear ends, SEMI-TRAILING arm, for FWD esp. vehicles. provides more cargo room & flatter floor
    - may use macpherson struts in front & semi-trailing arms in back
  - can be used in live axle setups w/ 2 or 3 links & a panhard rod - provides lateral location of the axle





- leaf springs: can also be used with a live axle, providing shock & lateral axle rigidity
- beam axle: one set of wheels is connected laterally by a single beam or shaft.
  - also called a solid axle
  - can be LIVE and have a shaft to transmit power
  - or can be DEAD and not carry power
- sway bar: stabilizer bar, anti-sway bar, roll bar, anti-roll bar, or ARB
  - connects a set of wheels with short lever arms on a torsion spring
  - suspension roll stiffness

Shock absorber

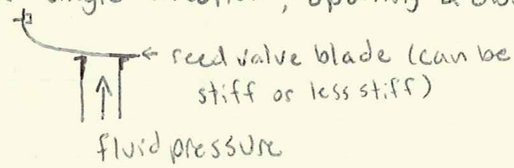


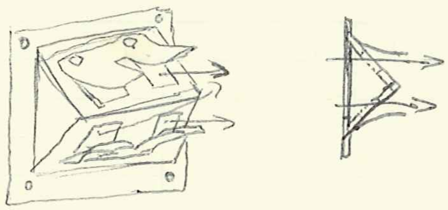
- the fluid-filled piston/& cylinder combination is a dashpot
  - energy is converted to heat: with hydraulic fluid, fluid heats up
  - linear dashpots; like shown, are specified by stroke and damping coefficient (Force per velocity)
  - bump (compression) damping control can be adjusted by air chamber ?
  - rebound damping control can be adjusted by oil reservoir ?

Valving - general term for restricting oil flow
- stiffness of valves determines amount of low-speed damping
- orifice size determines amount of high shaft speed damping

- combination of reed valve stiffness and orifice size combine to create different amounts of damping to different shaft speeds

Reed Valve: restricts the flow of fluids to a single direction, opening & closing under pressure (changing) on each face

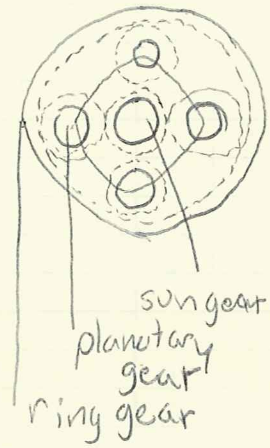




- rebound damping is typically about 3 times higher than compression damping.

* Koni sports for miata: 8041-1204 sport
  ground control springs F/R 375 / 250 = 6.71 / 4.475
  lbs/in to kg/mm, x .0179

Components: Ring gear - internal toothed
Sun gear - external tooth
Planetary gears - external toothed
carrier - affixed to planetary gears



Computations Zc (# of carrier teeth) $= Zr + Zs$
Zr = # of ring gear teeth
Zs = # sun gear teeth

Gear ratio $= \frac{Zc}{Zr}$ $\frac{\text{output teeth}}{\text{input teeth}}$

Held	Power input	output	speed	torque	rotation
Ring gear	sun	carrier	Reduced	opposite of speed	same
	carrier	sun	increased		
sun gear	ring	carrier	reduced		same
	carrier	ring	increased		
carrier	sun	ring	reduced		reversed
	ring	sun	increased		

* highlighted areas used in Toyota transmissions

- usually two ~~aut~~ planetary gear sets ~~and~~ that share 1 sun gear are found in an auto trans. to produce desired gear ratios

Holding devices for Planetary Gear Set
- Multiplate clutch - holds 2 rotating planetary components
- Brake - holds planetary components to housing
  * • multiplate brake
  • brake band
- Roller or sprag one-way clutch - holds planetary components in 1 rotational direction

Multiplate clutch: consists of drum, piston, o-ring, piston return spring, & snap ring & plates: <u>Discs</u> have teeth on inside to secure to splines on clutch hub are steel plates with friction material bonded
<u>Plates</u> have flanges outside to fit slots of drum or trans. case

Operation:
- hydraulic pressure causes the piston to act on clutch plates
- relief ball valve in piston body to release fluid when clutch diseng.
- some fluid rotating behind piston pushes on clutch & causes wear
  • relief ball valve designed to let that fluid out, centrifugal forces pull ball out of valve seat

Types 1) Front engine / Front drive (transaxle) - differential built in
2) Front engine / rear drive - differential is external

Components 1) Torque converter
2) planetary gear unit
3) hydraulic control unit (Valve body)

Torque converter - mounted on input side of transmission
- Drive plate / flex plate connects converter to crank flywheel flange
- drives the oil pump of hydraulic control system
- filled with auto. trans fluid
- serves as the flywheel
- components: 1) pump impeller
· integrated with case
· spins when crank spins
· throws fluid outward towards turbine
2) Turbine
· connected directly ~~towards~~ tranny input shaft
· receives power from impeller
3) Stator
· connected to stator reaction shaft, fixed to tranny case.
· redirects fluid on its way from impeller to turbine
· ONE WAY CLUTCH locks stator in opposite dir. of engine
↳ allows stator to spin same direction of engine
- flow of fluid
vortex flow - spirals between vanes of impeller & turbine
- high vortex flow when large diff. in ~~comp~~ speed of 2 components
rotary flow - at times of low vortex, one way clutch releases
- little need for torque multiplication
- greater when differences in speed are small
"coupling point" constant speeds, stator must spin

SErvices - contaminants in transmission fluid will also be in torque converter

Lockup clutch: locks impeller & turbine together
- speeds at ≈ 37 mph and higher
- installed on turbine hub in front of turbine
- when actuated, rotates w/ impeller & turbine
- fluid enters converter in front of lockup clutch ~~or~~ in main body of conv.
· pressure difference determines engagement
- fluid to control Lockup clutch also removes heat from converter & transfers it to engine cooling system through radiator heat exchanger
FLUid: Signal valve → relay valve → torque converter

Engine Sub Systems | 57 Emission #3

Intake valve deposits:
- absorb fuel & cause 'stumbling' of engine during accelleration
- causes lean mix when throttle is first opened & rich upon deceleration
- a bore-scope can be used to visually inspect valves for deposits without removing the head

Air induction System:
- requires that no air is introduced & unmeasured
- Unmeasured air leads to a/f ratio incorrect

Fuel Delivery System:
- maintain constant fuel pressure across injectors
- problems: 1) Injectors
  - leaky injectors, leaking f-pressure regulator diaphram,
  - faulty spray pattern
  - clogged injectors

- Fuel: - Antiknock index = octane rating
  - Knocking is combustion under pressure before spark
  - Volatility: ability to vaporize from liq. to gas cannot be too high/low
    - winter gas sold is usually higher volatility
  - Oxygenated fuels used now in some places
    - carrying compounds (ethanol or MTBE) contained
    - may cause economy loss in late O_2 detecting cars
    - older vehicles may see plastics swelling, result of alcohol

* Oil system: Wet sump, uses an oil pan to collect oil at bottom of crankcase 3~7 liters,
- limited size/capacity
- allows oil to slosh and pump run dry under high G's

Dry sump, uses external reservoir, any size, & pumps to reservoir + pumps to send to bearings

* not part of .pdf

- allows lower C.o G. with engine sitting lower
- more complicated
- does not run dry b/c oil cannot slosh away from pumps

Oil pump is usually a crank-driven pump with gears
- usually sucks oil out of oil pan through mesh screen & sends it through the oil filter then to bearings
- usually a spring-loaded preset relief valve routes oil back to source if pressure rises too high
- 4 bar is about normal maximum

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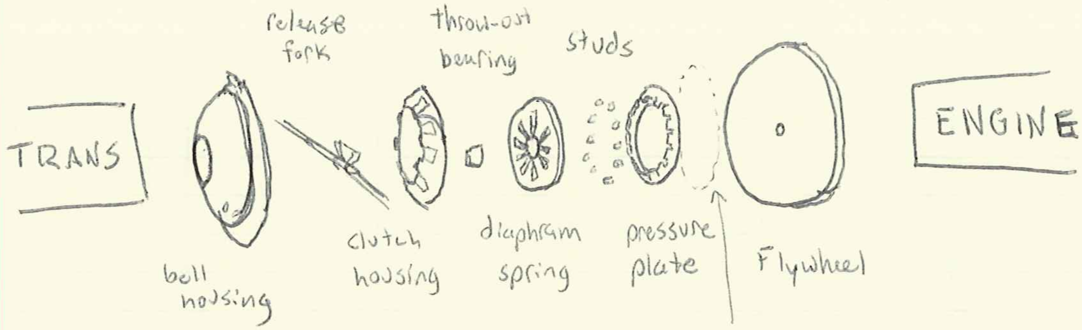
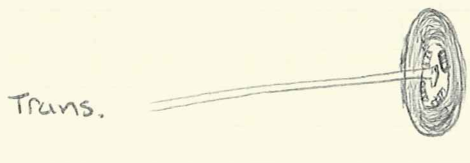
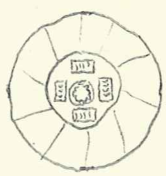
Clutch



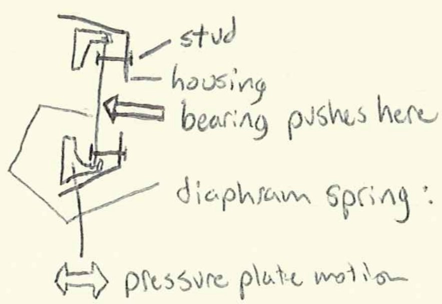


Releasing the clutch:
- On a hydraulic clutch, a piston releases from the release fork
- the release fork allows the throw-out bearing off the diaphram spring
- diaphram spring pushes back to flat position & applies pressure to pressure plate
- pressure plate pushes clutch plate against flywheel
  * clutch plate ~~fix~~ is fixed to transmission input with splines
- flywheel & clutch plate match speeds.



Clutch plate:
- springs help to isolate transmission from shock of clutch engaging
- friction material is like brake pad material

Diaphram spring does not spin. the Studs fix the spring to the housing

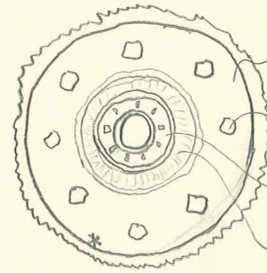


Stages: 1: stock clutch
2+: greater clamping, for mild tuning & less drivability
3+: racing clutch, high heat & require warming for performance

Differential, Mazda

— Old Diff —

- disassemble pumpkin
- Wipe off sealant from pumpkin gask.
- pull out bolts from ring gear (loctited)
- pull diff out
- hammer ring gear off of diff around edge here *

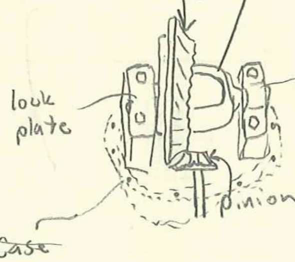


— New diff: —

- set onto ring gear, finger titen 2 bolts
- hammer lightly to start to sub.
- loctite all bolts & replace into ring gear
- ~~May be no torque specs for ring gear bolts - make'em tight.~~
  - use star pattern 51-61 ft.lb
- probably buy new bearings, press onto diff with bearing press
- setting new diff into pumpkin, make sure bearing race has NO debris.
- non-hardening sealant around pumpkin before replacing diff case (rtv blue?)

A&A auto salv.
LKQ auto salv.

1994-97 came with 4.10:1 diff part # for ring & pinion assy: M068-27-110A stamp: 1245
Clutch type LSD from '84-88 NA RX7, will bolt into latter '94+ miata housing
OEM RX7 Clutch type LSD has replaceable friction plates
1994+ miata 1.8L has 7" ring gear derived from 86-91 NA RX7 rear
but has shorter pinion & front pinion housing.



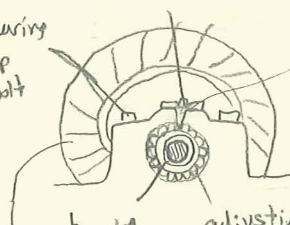
Half-shafts

miata 94+ flange 4x110 mm, same as 86-91Rx7
miata 94+ hub spline, 26 spline by 27mm diff side is same
miata, diameter, 22mm

My LSD: from '84-'88 Rx7

Tools for R&R of pinion, miata
- 0-1 in dial indicator, magnetic base
- 7-8" micrometer
- 5" bench vise
- Torque wrench
- Hammer
- Punch or Flathead screwdriver

- Thread lock
- Silicone RTV
- Shop rags
- bright paint pen



diff housing: .69 qts 90weight gear oil

Emissions

- Too low of intake air temps
  - cause fuel/air not to mix as well
  - can thus cause partial misfire

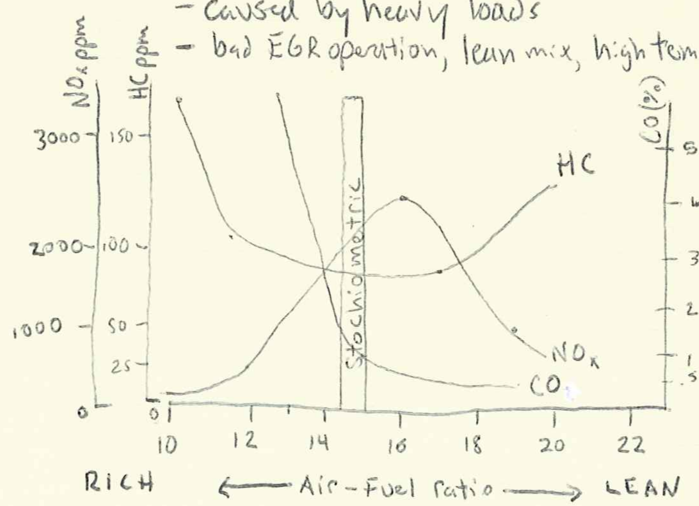
Misfire: fuel in a ~~x~~ firing cycle does not burn

- fuel contains Hydrocarbons
- Air contains N_2 & O_2 (78%) & (21%)

Ideal Combustion

$$N_2 + O_2 + HC's \rightarrow N_2 + H_2O + CO_2$$

- Hydrocarbons (HC's) basically mean unburnt fuel when they are emitted as exhaust
  - caused by deflagration not reaching very surface of cyl. walls
  - caused by fuel in carbon deposits not burning
- CO (carbon monoxide) a result of partially burned (or partially oxidized) fuel
  - caused by oxygen starved environment
  - caused by too rich mix, > stochiometry
  - caused by leaky injectors, high fuel pressure, improper c. loop ctrl.
- NO_x, oxides of Nitrogen
  - occur at higher temps & pressures
  - maggority NO, nitric oxide 98%
  - caused by heavy loads
  - bad EGR operation, lean mix, high temp intake air, xessive advance,



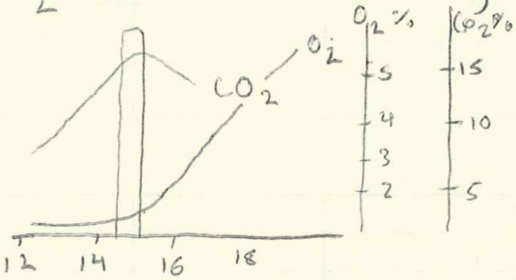
Charcoal Canister: A storage device in evaporative emissions control system
- small cylindrical or rectangular container
- contains activated charcoal
- traps gas. vapors from fuel tank & carb (if there's a carb)
- vapors are later purged & drawn into the engine when it is driven

VSV: vacuum switching valve
- one may be located inline from charcoal canister to the manifold or throttle body.
- may not cause 'check engine' if cc is removed.

IACV: Idle Air Control Valve
- IAC motor adjusts idle RPM by opening/closing an air bypass passage inside the throttle body
- the ECM sends signal to the IAC motor
- check if the motor works:
  - disconnect
  - turn car to 'on' but not 'start' & see if it moves

CO_2 (desireable) peaks in emissions @ stochiometric mix

O_2 indicates lean running
- caused by ~~lean~~ misfires
- caused by unburnt fuel



Other emissions not measured by shop analyzers
- water vapor ($H2O$)
- sulfur dioxide (SO_2) – created w/ S in gas → sometimes SO_3 → H_2SO_4 → ~~hyd~~ H sulfide gas (rotten odor)
- Hydrogen (H_2)
- particulate carbon soot (C) – visible black smoke of rich running

Causes of excess emissions listed in pdf, related to combustions
- HC emissions can also originate from evaporative sources – crankcase, fuel tank, EVAP system

Catalytic converter:
- introduces more O_2 into exhaust gasses: $\underbrace{HC + CO + O_2 \Rightarrow H_2O + CO_2}_{\text{NOT EXACTLY TRUE}}$

HC	ppm	unburned fuel
CO	%	combustion
NO_x	ppm	hightemp combustion (> 2500°F)
CO_2	%	efficient & complete combustion, theoretical max: 15.5%
O_2	%	unburned air

- Reduction: $NO_x + CO \Rightarrow N_2 + CO_2$
- Oxidation: $HC + CO + O2 \Rightarrow H_2O + CO_2$

EGR system (exhaust gas recirculation)

- main purpose is to reduce NO_x emissions
- lowers combustion temps, adds inert air to charge, increases specific heat capacity of the charge

- 5-15% of exhaust gasses routed back to intake
- EGR not enabled during idle & W.O.T. due to rough idle / power loss

FTP (Federal Test Procedure)

- regulations for emissions must be passed & adhered to by new vehicles
- ~~he~~ diagnostic executive controls EGR monitor & has 8 main monitors
  1) catalyst monitor
  2) EGR monitor
  3) EVAP monitor
  4) Fuel system monitor
  5) misfire monitor
  6) oxygen monitor
  7) oxygen heater monitor
  8) secondary air injection monitor

Oxygen sensor (O_2)

- ~~us~~ new vehicles have one before cat and one after the cat
- measures the difference between oxygen in atmosphere and exhaust gasses
  - changes its ~~voltage~~/ resistance depending on the difference
- cost about $80 & last 100,000 miles (for a heated sensor)
- most common design is a heated zirconia lambda sensor

Zirconia:
- a "narrow band" sensor that reads a narrow band of O_{xy} levels
- non linear, most sensitive around stochiometric point
- ideal setpoint at $\approx$ 0.45V DC, optimum A/F ratio

Heated:
- a heating element is used to warm the sensor
- sensor works at approx 800°C / 1,500°F
- 2 wires for lambda output, 2 wires for heater power (or 3 total w/ common g.)

Failure:
- burning rich, burning oil, or coolant can contaminate
- soot can probably be wiped off to help function
- can possibly be cleared of carbon deposits:
  - heat probe w/ butane torch to almost red
  - dunk in cool water and quickly blow off w/ air sprayer
- symptoms are ↑ emissions, MPG ↓, hesitation, rough idling

Secondary Air Injection

Purpose: Send extra air into exhaust System before cat. converter & provide O_2 for gasses to finish burning/ oxidizing & help cat~~p~~alyst oxidation. reduces HC & CO emissions entering cat.

How it works: Exhaust pressures pulsate between above/below atmospheric pressure.
PAIR (~~pulsating~~ pulsed secondary air injection) Valve operates after intake resonator, like EGR, to allow/not allow secondary air.
- uses pressure diff in exhaust vac pulsation / atmosphere to feed
- has reed-style check valve to stop backflow

— an ECM controlled VSV (vacuum switching valve) alters signal to PAIR valve in vacuum line.
- it is normally closed
- opens during high emissions (ie. cold engine/ deceleration)
-

— PAIR system intake hose to air cleaner will have pulsating noise when open

Resonator: • in intake, ~~after~~ used to baffle air pulsation that normally occurs during system operation

Ignition

IGnition Systems

Distributorless ignition systems:

- spark timing is contlolled by an Ignition Control Unit (ICU), also called Ignition Control Module (ICM), and the engine computer
- frequently uses one coil per cylinder or per pair of cylinders
  - pairing often uses wasted spark system, firing both atonce - one is at ignition and one is on exhaust stroke
- magnetic triggering device such as crank or cam position sensor sends signal to ~~ECM~~ ignition ~~module~~ control module (ICM)
- engine ecu tells ignition module when to fire

Coils - steps up voltage from 12V battery to usually 25,000V
- will be worn on if spark gap is too large
  - * includes disconnected spark plug, sparkplug far from ground, etc.

PCM: powertrain control module
ECM: engine control module
ECU: Engine control unit
EMS: Engine management system
} names for same thing

MSD: ignition parts manufacturer
DIS: distributorless ignition system
ICM: ignition control module

Battery

Wet cell: liquid electrolyte, sulfuric acid, is maintained by replacing water that boils off during normal cycling.

- water can slosh & spill in car
- 3 years average car battery

Gel cell: electrolyte is fixed by silica gel & does not slosh.

AGM (Absorption Glass Mat): evolution of other batteries, sealed battery

- sulfuric acid is absorbed between lead plates & immobilized by a fine fiberglass mat
- allows smaller battery to create the same power

* miata has a panasonic AGM battery, 440 Cold Cranking Amps

Ignition System - coil pack

2 voltages go into coil pack (miata)
- 1) 0.5 - 0.8 v from computer to the ignitor (signal voltage)
- 2) 12 volts from computer (primary voltage)

primary voltage:
- always on to the coil pack when key is on
- igniter doesn't let it until it receives signal from computer
- turns on for 5.5 miliseconds w/voltage from .5 building to .8 volts & immediately falls, then primary is shut off
- ~~does not turn on if~~ shutting out causes secondary voltage

Signal voltage
- looks like inverted 'v'
- does not turn on (not generated by computer) if primary is overloaded
- not generated if "engine fuse" is blown

- secondary voltage (to spark plugs)
  - comes out of coil pack to spark plugs @ 17,000 + volts

Shorts in ignition:
- heat, vibration or ground issues can cause shorts
- too large spark plug gap can wear out coil pack

Turbos cont'd. Compressors - trim $(\text{inducer } D / \text{exducer } D)^2 \times 100$

- inducers that are ~~too~~ large create more flow
  - too large will cause more lag on turbo spooling
  - too ~~sm~~ large can cause <u>surge</u>: more air than engine can swallow
    - * can cause reverse pressure waves & damage turbo
- exducers increased in size
  - reduces spoolup time
  - builds boost faster & increase pressure ratio capability of compressor
- compressor flow maps
  - airflow, compressor efficiency, pressure ratio, shaft speed
  - x-axis = air flow
  - y-axis = pressure ratio (manifold pressure / ambient pressure)

Ignition Systems - Very basic

Electronic Ignition

1) angular sensor, optical or magnetic Hall effect sensor
   - hall effect sensor varies voltage in response to passing magnet
   - this sensor in cars tells RPM
   - crank sensors tell crank rpm, ~~somet~~
   - sometimes cam position sensor is also used, esp for variable valve timing
     - crank sensors are often located on main crank pulley or flywheel

Mechanically timed ignition:

1) Distributor
   - rotating cam driven by engine drive
   - breaker points, condenser, rotor, dist. cap.
2) ignition coil
   - transformer from 12V engine battery to 1,000's of volts for spark
   - modern engines* have 1 coil per 1 or 2 cylinders
   - coil location
     A) remote-mounted OR
     B) located on top of spark plug (coil-on-plug / direct ignition)

   * ~~with never~~ modern engines do not have mechanically-timed ignition, distribution is done electronically.

     C) individual coils mounted together is called a <u>coilpack</u>
   - electronic ignition switches & sends low voltages; less problematic, esp. w/damp conditions. low voltages amplified by coils.

300zx

vin:
mileage:
Year?
Equipment Package?
tires hold air?
tire tread?
engine problems:
transmission problems:
power: windows ☐ door locks ☐ mirrors ☐
missing parts?
4th wheel or spare
radio?
speakers?
leaks?
engine turns over?

Combustion times: dependant on air/fuel mixture
lean mix = slow combustion, used for less load
rich mix = fast combustion, used when more load is on engine, for more power

Timing advance
- greater for lean mix/ ~~fa~~ slow combustion
- less for rich mix/fast combustion

Devices: Manifold Absolute Pressure sensor: (MAP)
- to calculate air density & air mass flow rate to engine
- is alternative to MAF sensor (mass air flow)
- Used with engine RPM, & air temp to calculate speed-density

Mass Airflow Sensor (MAF)
- calculates mass of air entering fuel-injected engine
- insensitive to density of fluid
- two common types:
  1) vane meter
  2) hot wire
- both send a 0-5.0 volt signal to ECU

Vane meter a vane/paddle on a spring loaded arm in intake air stream
- measures volume only. requires temp & pressure readings too

Hot Wire sensor wire heated by current in airstream
- output current is current required to maintain hot wire in equilibrium
  - doesnt restrict airflow
  - can be contaminated w/ dirt ≈ poorer accuracy
  - requires LAMINAR FLOW (not turbulent)

Oxygen Sensor
- measures proportion of oxygen in fluid being analyzed
- Usually used in exhaust of combustion engines
- help determine air fuel ratio
  - Why it is important: pollutants & power
    1) Hydrocarbons, result of unburnt fuel ~ rich mixture
    2) Oxides of Nitrogen, NO_x gasses, occur at combustion > 2000°F
       note! most powerful combustion coincides with ignition advances greater than stock, combustion > 2000°F, & NO_x emissions & CO emissions > legal.

* timing advance decreases fuel consumption ≈ lean

Engine load: how much the engine is pushing: friction, pumping, car,
- high load = high cylinder pressures, cylinder temps, exhaust temps
- low load = lower cylinder pressures, cylinder temps, exhaust temps

Engine "Blow-By"
- this is small ammounts of unburned fuel and exhaust that escape around piston rings
- blow-by enters crankcase
- PCV valve exhausts blowby into intake manifold of the car.
  - in non-turbo, intake manifold draws blow-by by having lower pressure than crankcase
- PCV = Positive Crankcase Ventilation
  - usually a simple one-way valve
  - turbo engines usually have a check valve to stop pressure from → crankcase

Oil Circulation: Wet-sump system:
- oil sits in oil pan at bottom of crankcase

Dry-sump system:
- oil held in an external reservoir

- ~~oil does not~~ sump oil has minimal contact with crank in wet sump to avoid frothing.
- oil squirts on crank bearing, connecting rod bearings, cylinder walls, drips into crankcase

Timing advance	Condition
<	greater load
>	lighter load
>	high RPM
<	Low RPM

Fuel system

Fuel Injection

Fuel Injection has been used in the states <u>exclusively</u> since 1990

Electronic Fuel Injection

1) Throttle-body fuel injection systems:
   - developed first, nearly a bolt-on replacement for a carb
   - also called single-point or central fuel injection
2) MPFI multi-point fuel injection, or sequential fuel injection, or port F.I.
   - usually sprayed right at intake valve
   - one injector for each cylinder
     - more accurate fuel metering & quicker response
3) Central Port FI
   - similar to throttle body, w/ 1 injector
   - has tubes with poppet valves going to individual ports
4) Direct Injection
   - injection nozzle placed in combustion chamber of each piston
   - used in many diesels, starting to be used in gasoline engines
   - allows for better dispersion, more homogeneous fuelling
     - allows for higher compression and more aggressive timing
     - can use piezoelectric injectors that respond to mechanical stress ~ FAST

Fuel Injectors

- solenoid valve that allows fuel to pass
  - solenoid "on" means fuel "on"
  - valve spring returns solenoid to "off"
- controlled fuel ammounts by pulse width
  - pulse width measured in miliseconds/intake stroke
  - P.W. usually range from 4ms at idle to 35 ms @ WOT
  - P.W. accuracy is about 0.01ms
  - fuel/air stochimetric for gasoline is 1/14.64

Fuel Pump

1) mechanical pumps
   - usually used with carbeurated engines
   - positive displacement diaphram, usually attached to crankcase
   - fuel pressure limited ~~by~~ by diaphram spring (mechanical)
2) electric pumps
   - can create higher pressures (40-60 psi)
   - usually located in the fuel tank, submerged in fuel
   - sometimes cars have interstia switch or roll over valve to shut off pump

Injectors

example: Precision 525 cc injectors

Flow rate	HP per injector	Impedance	Resistance:
525cc	85	High	12 ohm

* 525cc/min = 52lb/hr

* low impedance injectors require a resistor box or inline resistors
* high imp. injectors do not require resistor box (92-00 civics do not have a factory resistor box)
* horsepower ratings calculated at 90% duty cycle at 43.5psi, upon BFSC of .50

Flow rate: volume of fuel per minute

6000 RPM = 0.01 seconds per revolution, only 10 milliseconds time for one stroke

Injector ~~opening~~ time will be half of the value when injector flow rate is doubled
- larger injectors will require more time to open (possibly .5-3ms)
- higher voltage battery will cause injector solenoids to act faster

Choosing injectors
- good to have a flow rate that can flow proper ammount at 80% duty, to allow for boost spikes, cold weather, fault conditions
- if fuel rail pressure is decreased, flow increase may not have effect
- check A/F ratio results w/ a lambda (wideband) device

What is Lambda?

lambda = Mass AFR during combustion
- lambda = 1 stoichiometric
- lambda <1 mixture is rich
- lambda >1 mixture is lean

- narrowband: values between 14.1:1 to 15.4:1 readout, switching sharply rich to lean
  - provides rich/lean result but not to what degree
  - not accurate enough for tuning
- wideband: designed to give exact lambda reading, range as great as .7 to 32 lambda
  - 5 wire type: newer tech, better acc., measures sensor voltage output + current required
  - 4 wire type: ~~Stoic~~ voltage shows oxygen differential in exhaust/atmosph, + temp. of sensor as sensor impedance varies w/ temp. can have errors up to 8%
- typical tune: peak power at .84 ~ .90, best economy @ 1.05, best emissions just under 1.

Knock sensor

Location: engine block, cylinder head, or intake manifold

Construction: diaphram on piezoelectric sensor w/ high voltage on knock

- engine knock occurs within a specific frequency range
  the knock sensor is tuned to detect that frequency

Turboos

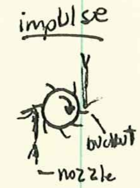
Turbos Background:

- avg Sea-level pressure is 101.325 kPa, or 14.7 psi
- powered by engine exhaust-driven turbine

Turbines:

1) Impulse turbines
   - change direction of flow of a high velocity fluid jet
2) Reaction turbines
   - creates torque by reacting to a fluid's pressure or weight
   - must contain the working fluid in casing or be immersed

- since liquids are incompressible, liquid turbines have 1 stage
- stator is the stationary part of a turbine
- rotor is the rotating part



Compressors:

1) Dynamic
   A) axial: uses aerofoils rotating, progressively compressing fluid
      - high flow rates
      - compact design
   B) centrifugal
      - use rotating disk or impeller to increase ~~speed~~ gas velocity
      - use diffuser to convert velocity to pressure
        - a diffuser simply slows the flow & static pressure increases
2) Positive Displacement
   - directly compresses a fluid, using pistons, rotary screws, scroll pumps, or diaphrams
   - when used with gas, often multiple stages are used esp. for pistons (reciprocating compressor) & diaphrams

Intercoolers:

- Front mounted, (FMIC) top mounted (TMIC) hybrid mount (HMIC)
- air to liquid, air to air
- lower temps & pressures of intake gasses, increase density
- 300zx uses side mounted air to air (twin turbo)
- exhaust gasses in turbine of turbo usually 450°C/840°F
- FMIC uses air from front, TMIC hood scoops,

-Goal: within 20° of ambient temperature is good

Turbines: components & specs

- A/R ratio = Area of housing (turbine) beginning / radius from wheel center to inlet area center
- stages NOT universal, mfr's differentiate turbine wheels Stage I, II, III
  - less exhaust backpressure = slower turbine spin = breathe-easy xhaust
  - aggressive turbine, (more flow) = more peak h/p but less boost

Compressors:

- inducer ~~takes~~ 'bites' air initially, exducer 'shoots' compressed air out.
- <u>trim</u> = (minor (ind.) diam / major (exd.) diam)$^2 \times 100$
  - larger trim generally has more flow

Turbos cont'd:

Wastegate: valve that diverts exhaust gasses from the turbine

1) External: usually used for more precise regulation of boost pressures
   - Used in high power turbochargers
   - can be used with internal wastegate welded shut
   - Used sometimes with no internal wastegate *never more than 1 wastegate*

2) Internal: built into turbine section of turbo

3) Divorced: dumps air directly out to atmosphere instead of into exhaust
   - reduces overall backpressure on exhaust system
   - has dumper pipes, or "screamer pipes"
   - usually only found on ~~int~~ external wastegate

4) Control:
   - Pneumatic, electric, or hydraulic.
     - most cars have pneumatic
   - Pneumatic control:
     A) single port - have 1 line from charge to Boost control solenoid
     B) dual port - adds second port, on opposite side of actuator
     C) can be controlled with electronic boost controller
       - description of a boost controller
       manual: t-fitting on a boost control line with a small bleeder screw that adjusts pressure going to the wastegate actuator
   - wastegate actuator:
     - controlled by a spring, compressed by air from boost control line
       - for ex, a 7 lb spring. problem: may partially open far prior to 7psi
   - Electronic control
     - An EMS, (Engine Management System) can control bleeding on T-line so that turbo charger will boost to higher levels than normal, up to a set maximum

     ex.) ~~this would~~ where a 7psi wastegate spring may open a wastegate partially at 3.5psi, the EMS would bleed the T-line until actual pressure is 7psi so that boost is built faster

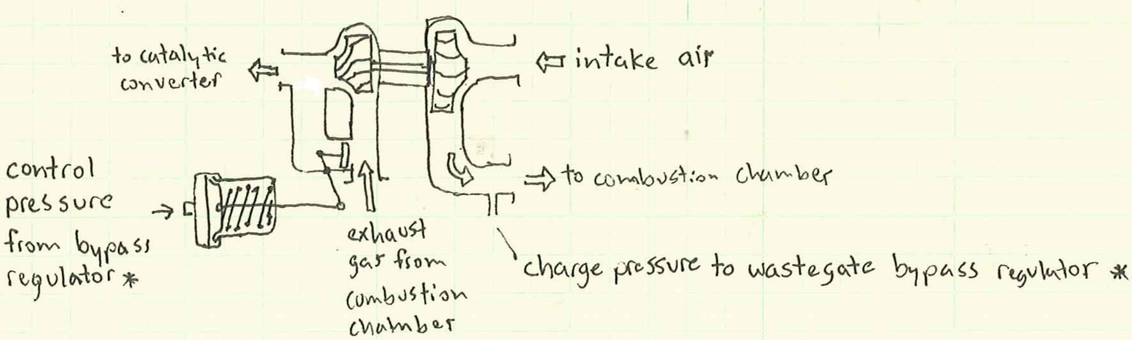
     - boost controllers often use PWM (pulse width modulation) to sometimes underreport pressures to wastegate actuator as in above example.
     - Electronic boost controllers are made by A'PEXi, Turbosmart, GReddy, Gizzmo Electronics, etc.
     - the boost controller ultimately sends a signal to a solenoid that controlls bleeding
       A) the solenoid is a binary device, controlled digitally
       B) Stepper motors sometimes used in conjunction with the solenoid to make fine adj., while solenoid does coarse adjustments

Blowoff valve: pressure release for downstream of compressor

1) Compressor bypass valve (CBV)
   - aka ~~to~~ compressor relief valve / diverter valve
   - Vacuum-activated valve that sends pressure back to non pressurized part of intake (post- MAF sensor)
     a) protects engine from compressor surge
     b) does not release air as to confuse MAF sensor
2) blowoff valve (BOV) NOT dump valve
   - releases air from post-compressor to atmosphere
   - may confuse ECU because it changes from MAF reading
     a) can correct using fuel controller that supports MAP instead of MAF
3) Dump valve
   - fitted between compressor & throttle
   - has a preset spring pressure for automatic dump to-atmosphere.
   - less elegant/customizable than blowoff valve

- difference between blowoff & dump valve is that blowoff has vacuum connected ~~to~~ after throttle plate
  - low pressure occurs after throttle plate when throttle is closed that sucks BOV open

Turbo / wastegate Diagram:



Turbos - models

Garrett GT2560R-1 (GT28R) dual ball bearing turbo with wastegate (internal)
Turbine: 53mm - 62 trim / .64 AR
Compressor: 60mm - 60 trim / .60 AR
Approx 310 hp flow capacity

GT2554R -
T: 53mm - 62 trim .64 A/R
C: 54.3mm - w/60 trim .80 A/R

- Used RX7 460cc fuel injectors
- keep stock fuel pump until it dies, then buy
- buy MS (Mega squirt) not necessarily pnp

Brakes

Brakes

Drum Brakes
- drum brakes apply pressure to the inner surface of the drum

Design: 1) Leading/tailing
- has two 'shoes' moved by a single acting hydraulic cylinder
- One shoe will bite harder w/ car moving forward, } due to design
- second shoe will bite harder backwards

2) Twin leading
- both shoes grab in direction of forward movement
- has more forward stopping power, less backwards

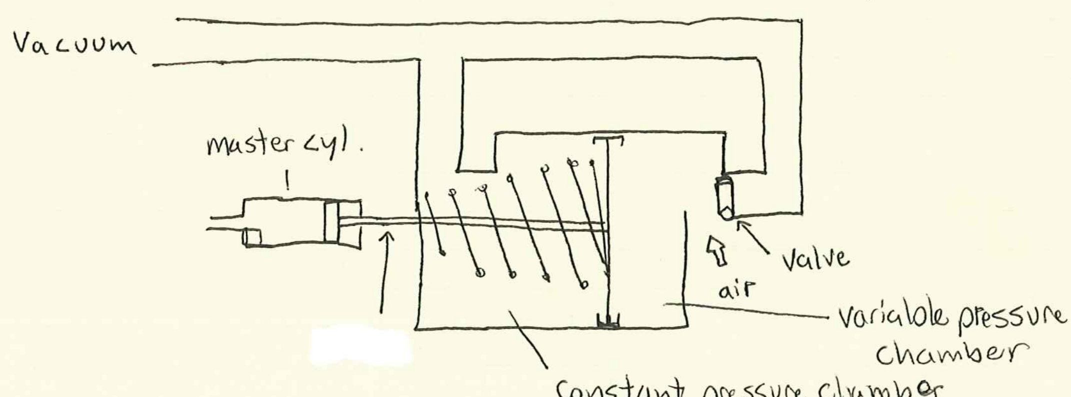
3) Arrangement
- often the best arrangement has twin leading drums in front and leading/tailing in rear
- drums are usually used for parking brakes (simple incorporation)
- all-around disc equipped cars often have drums for parking fitted inside or part of rear disc

Disadvantage: - do not shed heat as well as discs
- brake fade occurs when they overheat
- water in drums will reduce braking power

Adjustment - modern drums have a built-in auto adjustment that adjusts for ~~brake~~ drum & shoe wear

Brake Booster
- uses vacuum from the manifold to add power to the brakes

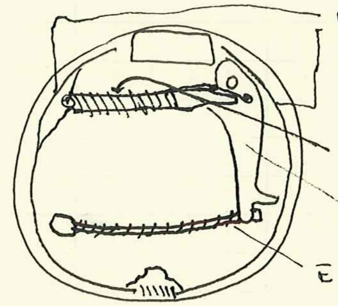
Components 1) vacuum chambers:
- two chambers, when both are sealed, spring pushes piston to neutral
  - when 1 chamber at atmospheric pressure, ~~spring~~ piston is forced to compress ~~ma~~ towards master cylinder



Parking Brake: 3 styles –
1) – 2 use the service brake, & 1 is exclusive parking break design

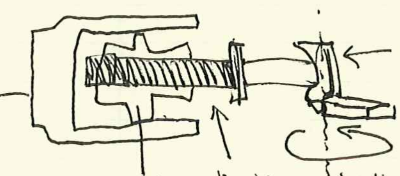
Linkage components
brake lever & cable
intermediate lever (multiplies force)
pull rod
equalizer (sends force to both tires

Drum type parking brake



- the cable pulls the E brake lever & transfers the lever action to primary shoe through the shoe strut

Disc parking brake
- Caliper parking brake
  - has automatic adjusting mechanism consisting of:
    - clutch spring, ~~to~~ sleeve nut and adjusting bolt.
  - this assembly advances the piston as the pads wear, an equal ammount to the wear
  - the piston head has two recesses to allow a tool to screw it back in.
    * one recess fits within the pin on back of the pad to keep it from rotating. when assembled
  - pulling brake lever rotates a crank lever that causes crank pin to push the strut towards the brake pad (like cam pushing a valve stem)



Exclusive Parking Brake
- has assembly like conventional drum brake fitted inside drum that's cast into disc rotor
- has ~~screw~~ shoe adjusting screw set, must be adjusted manually as pads wear

Brakes

Brake fluid:

- Required by SAE & DOT
  - remain viscous
  - have a high boiling point
  - act as a lubricant for moving parts

Types 1) Polyglycol
- attracts/absorbs water
- Clear/Amber
- solvent - emmediately begins dissolving paint
- DOT3, DOT4 categories, will blend w/ eachother

2) Silicone
- purple color
- higher boiling point
- will not harm paint
- has > affinity for air & harder to bleed

Master cylinder:

Setups
1) FR vehicles route 1 circuit of brakes to front & 1 rear **CONVENTIONAL**
2) FF often use diagonal circuits to 1 Front & 1 rear tire on each circuit **DIAGONAL**

Components
- single bore, separated into 2 chambers
  - rubber piston cups on front & rear chambers
    * 2 on each chamber
- primary piston is linked to brake pedal via pushrod
- return springs act on both primary & secondary pistons
- resting position is cups between inlet & compensating ports
- reservoir tank of plastic resin, cylinders of cast iron/alum. alloy
- orifices in piston cups allow flow from inlet port into cylinders upon brake release to prevent vacuum & drawing air in from wheel cylinders
- Dual reservoir type has 1 extra piston cup to seal 2nd cyl from 1st

Brake Rotor:

- usually made of cast iron or ceramic composites
- Cross drilled: holes drilled through the rotor, allows place for gas to escape (if Brake pads outgas or.. puddles) also heat dissipation. modern pads do not outgas much
  - discs may eventually crack at holes
- slotted: shallow channels machined into rotors
  - wear down pads quickly
  - aid in removing dust & gas
  - preferred to cross-drilled in racing
- two piece: have outer portion of rotor (rotor ring) bolted to inner portion (hat)
  - only the disc needs to be changed
  - floating disc: has oblong holes to allow expansion/contraction
  - non-floating: lighter, less expensive, don't allow for heat cycle expansion
  - hat is often aluminum, ring is steel

Brakes

Bleeding brakes:

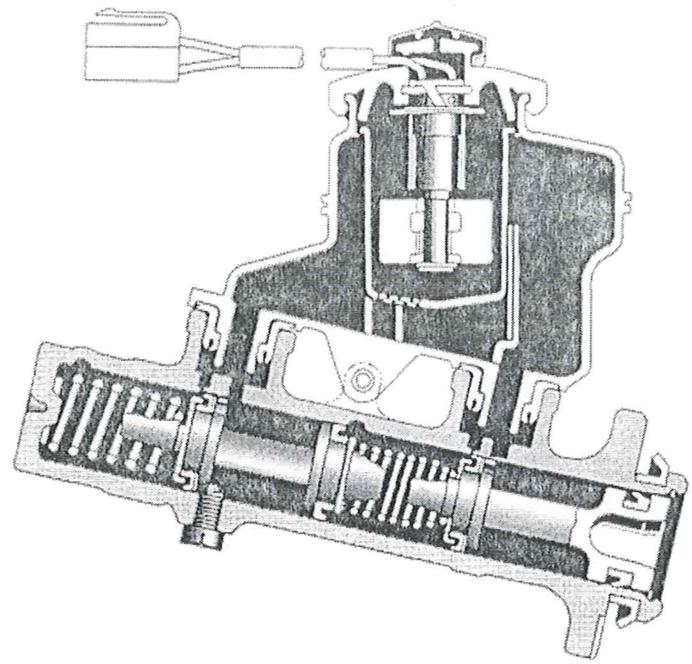
- if fluid gets too low in reservoir, air bubbles can enter brake lines
- fluid degrades
    - atmospheric dirt & abrasive metal wear particles contaminate
    - moisture from air absorbs into fluid, ~~raising~~ lowering boiling temp.

1) suck old fluid out of reservoir & top off w/ fresh fluid
2) regularly refill reservoir as brakes are bled, will maybe use (2) 8oz cans
3) jack up car & pull tires
4) get wrench to fit bleeder bolts, use penetrating oil & tap with hammer if they are stuck
5) attach a tube to bleeder bolt & one end in a bottle w/ a little fresh fluid top off & cap off the MC reservoir
6) with a helper: ~~apply~~ start on LR, then RR, then Front
    - apply pressure to brake pedal
    - crack bleeder & let it flow
    - close bleeder.
    - release brake pedal.
    - repeat steps until clean fluid comes through brakes

* this works for non ABS but maybe not ABS!

Section 2

MASTER CYLINDER



Lesson Objectives

1. Explain the difference between conventional and diagonal split piping system and their application.
2. Describe the function of the compensating port of the master cylinder.
3. Explain the operation of the residual check valve on the drum brake circuit of the master cylinder.
4. Explain the safety advantage of having two hydraulic circuits in the master cylinder.
5. Describe the difference between the Portless and Lockheed master cylinders.

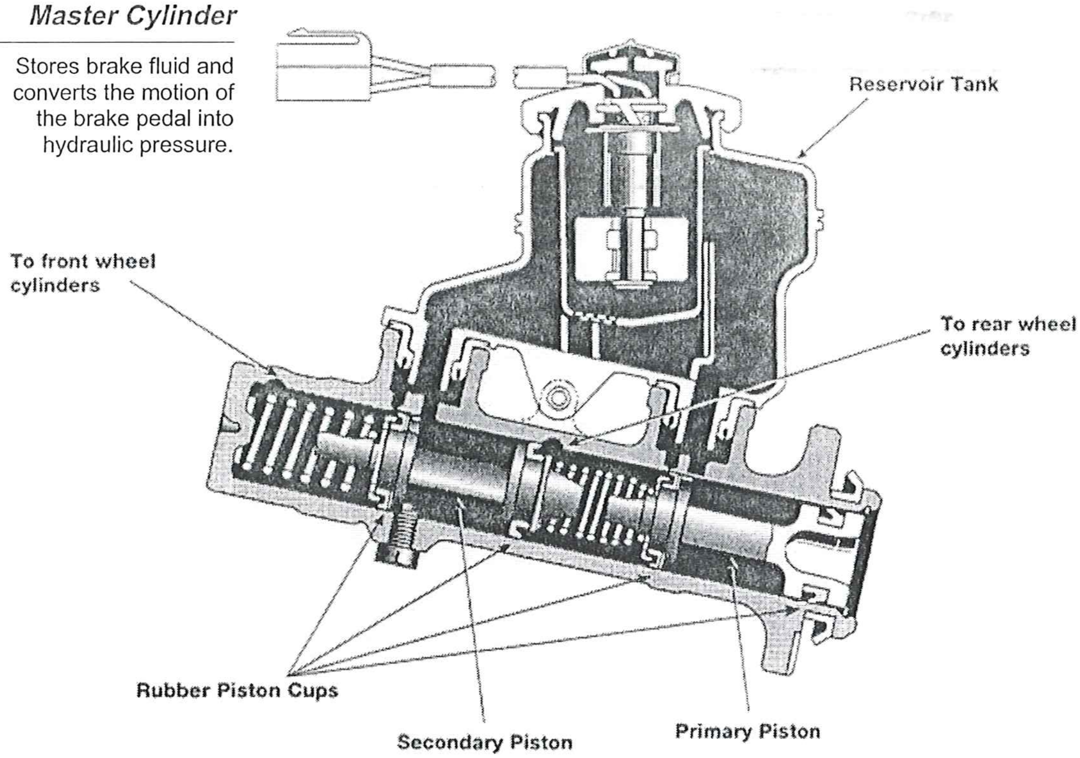
Master Cylinder

The master cylinder converts the motion of the brake pedal into hydraulic pressure. It consists of the reservoir tank, which contains the brake fluid; and the piston and cylinder which generate the hydraulic pressure.

The reservoir tank is made mainly of synthetic resin, while the cylinders are made of cast iron or an aluminum alloy.

Master Cylinder

Stores brake fluid and converts the motion of the brake pedal into hydraulic pressure.



Tandem Master Cylinder

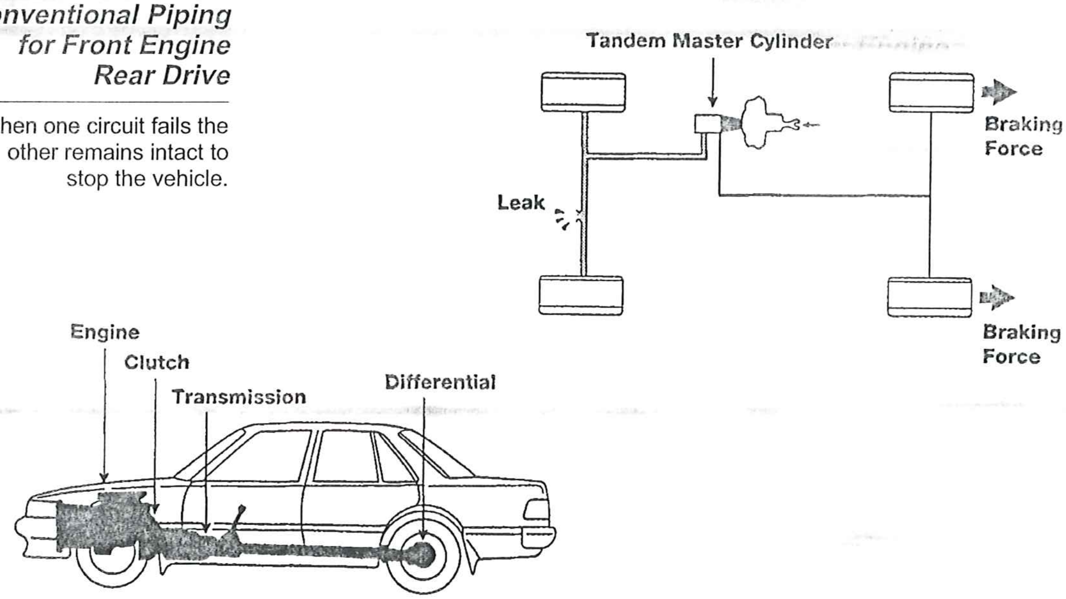
The tandem master cylinder has two separate hydraulic chambers. This creates in effect two separate hydraulic braking circuits. If one of these circuits becomes inoperative, the other circuit can still function to stop the vehicle. Stopping distance is increased significantly, however, when operating on only one braking circuit. This is one of the vehicles' most important safety features.

Conventional Piping

On front-engine rear-wheel-drive vehicles, one of the chambers provides hydraulic pressure for the front brakes while the other provides pressure for the rear.

Conventional Piping for Front Engine Rear Drive

When one circuit fails the other remains intact to stop the vehicle.

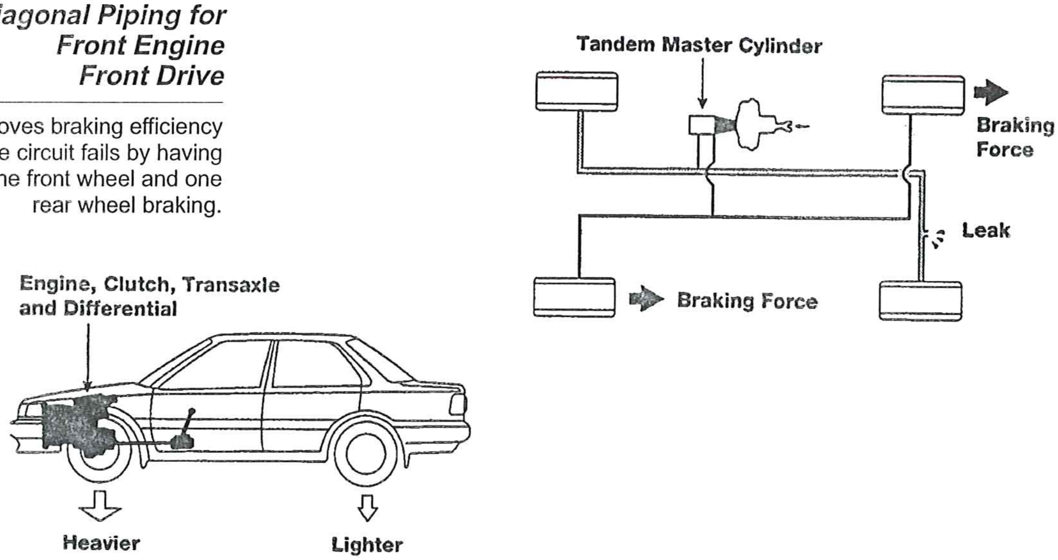


Diagonal Split Piping

On front-engine front-wheel-drive vehicles, however, extra braking load is shifted to the front brakes due to reduced weight in the rear. To compensate for hydraulic failure in the front brake circuit with the lighter rear axle weight, a diagonal brake line system is used. This consists of one brake system for the right front and left rear wheels, and a separate system for the left front and right rear wheels. Braking efficiency remains equal on both sides of the vehicle (but with only half the normal braking power) even if one of the two separate systems should have a problem.

Diagonal Piping for Front Engine Front Drive

Improves braking efficiency if one circuit fails by having one front wheel and one rear wheel braking.



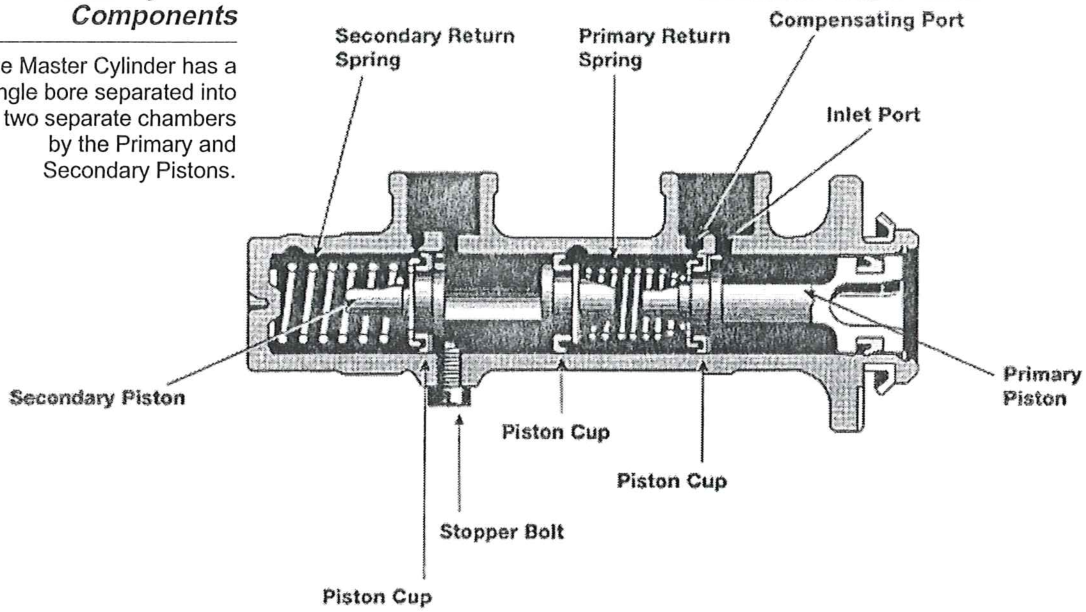
Construction

The Master Cylinder has a single bore separated into two separate chambers by the Primary and Secondary Pistons. On the front of the master cylinder Primary Piston is a rubber Piston Cup, which seals the Primary Circuit of the cylinder. Another Piston Cup is also fitted at the rear of the Primary Piston to prevent the brake fluid from leaking out of the rear of the cylinder.

At the front of the Secondary Piston is a Piston Cup which seals the Secondary Circuit. At the rear of the Secondary Piston the other Piston Cup seals the Secondary Cylinder from the Primary Cylinder. The Primary Piston is linked to the brake pedal via a pushrod.

Master Cylinder Components

The Master Cylinder has a single bore separated into two separate chambers by the Primary and Secondary Pistons.



Normal Operation

When the brakes are not applied, the piston cups of the Primary and Secondary Pistons are positioned between the Inlet Port and the Compensating Port. This provides a passage between the cylinder and the reservoir tank.

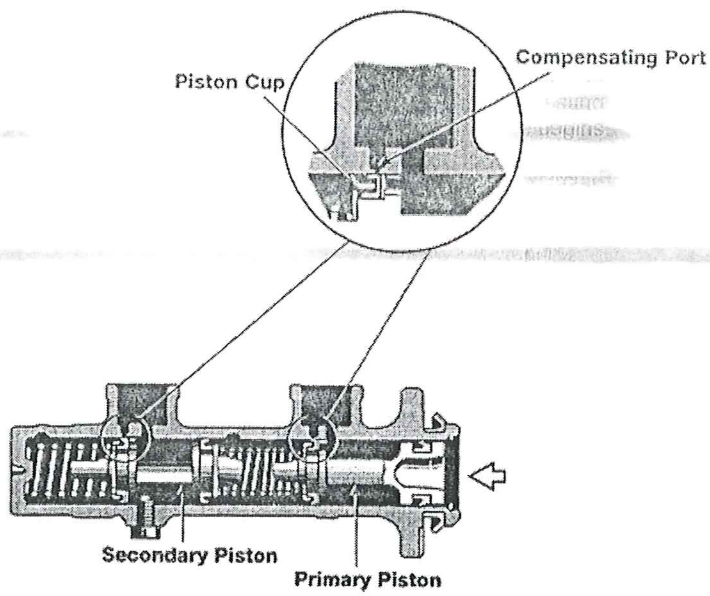
The Secondary Piston is pushed to the right by the force of Secondary Return Spring, but prevented from going any further by a stopper bolt.

When the brake pedal is depressed, the Primary Piston moves to the left. The piston cup seals the Compensating Port blocking the passage between the Primary Pressure Chamber and the Reservoir Tank. As the piston is pushed farther, it builds hydraulic pressure inside the cylinder and is applied or transmitted to the wheel cylinders in that circuit. The same hydraulic pressure is also applied to the Secondary

Piston. Hydraulic pressure in the Primary Chamber moves the Secondary Piston to the left also. After the Compensating Port of the Secondary Chamber is closed, fluid pressure builds and is transmitted to the secondary circuit.

Brake Application

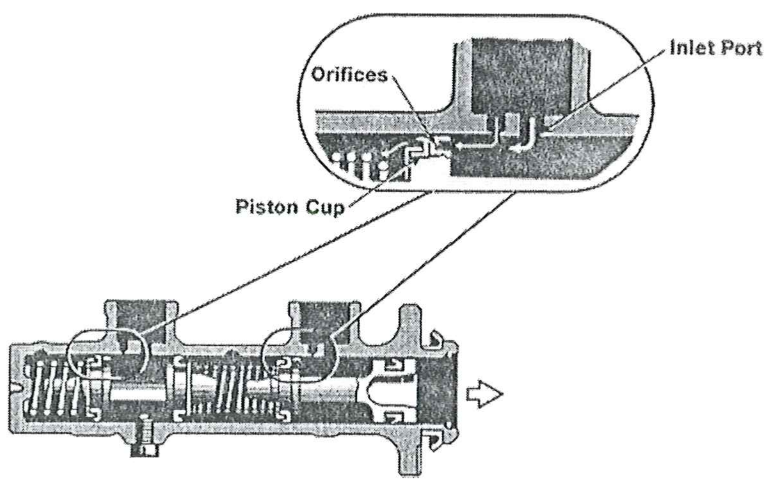
As the piston cup passes the compensating Port pressure begins to increase in the hydraulic circuit.



When the brake pedal is released, the pistons are returned to their original position by hydraulic pressure and the force of the return springs. However, because the brake fluid does not return to the master cylinder immediately, the hydraulic pressure inside the cylinder drops momentarily. As a result, the brake fluid inside the reservoir tank flows into the cylinder via the inlet port, through small holes provided at the front of the piston, and around the piston cup. This design prevents vacuum from developing and allowing air to enter at the wheel cylinders.

Brake Release

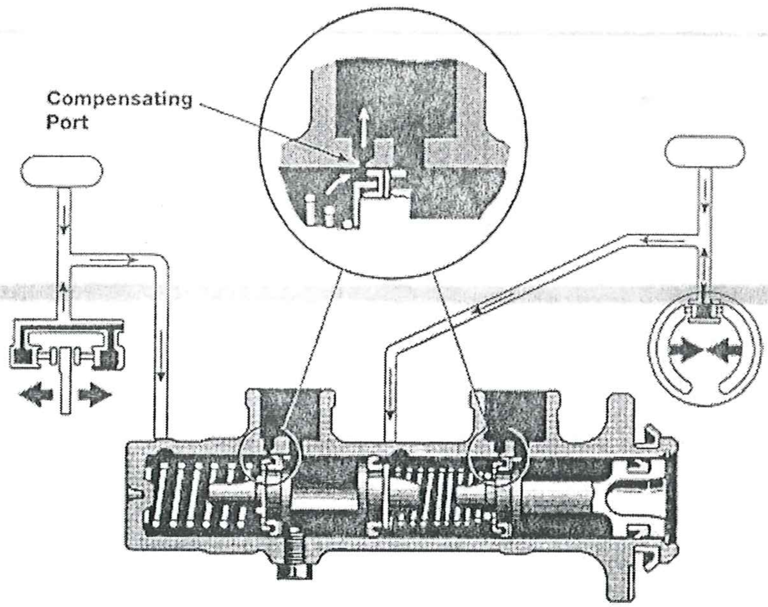
Brake fluid inside the reservoir tank flows into the cylinder via the inlet port, through small holes provided at the front of the piston, and around the piston cup.



After the piston has returned to its original position, fluid returns from the wheel cylinder circuit to the reservoir through the Compensating Port.

Fluid Return

Fluid returns to the reservoir tank through the compensating port.

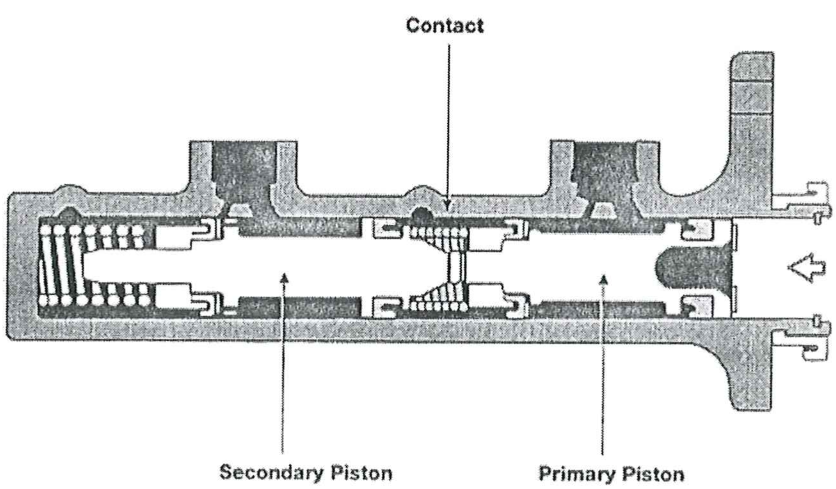


Fluid Leakage In One of the Hydraulic Circuits

When fluid leakage occurs in the primary side of the master cylinder, the Primary Piston moves to the left but does not create hydraulic pressure in the primary pressure chamber. The Primary Piston therefore compresses the Primary Return Spring, contacting the Secondary Piston and directly moving the Secondary Piston. The Secondary Piston then increases hydraulic pressure in the Secondary Circuit end of the master cylinder, which allows two of the brakes to operate.

Leakage In Primary Circuit

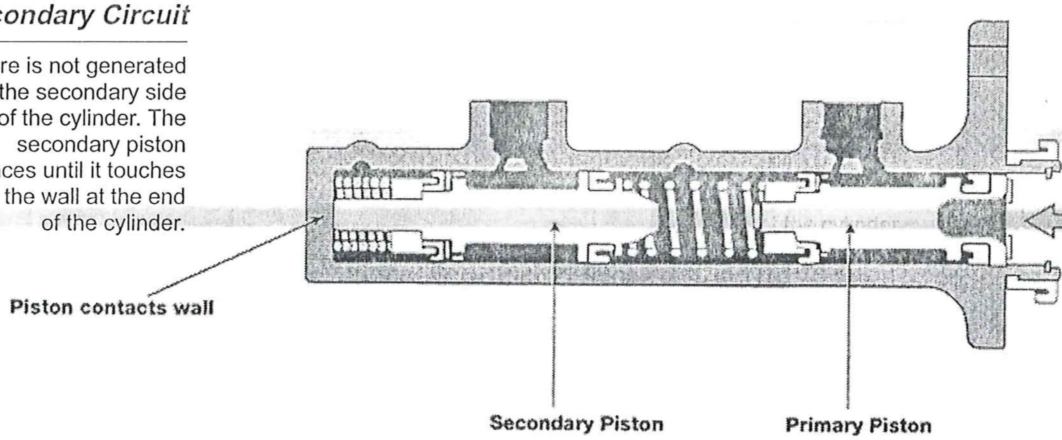
The primary piston compresses the return spring, contacts the secondary piston, and manually moves it.



When fluid leakage occurs on the secondary side of the master cylinder, hydraulic pressure in the Primary Chamber easily forces the Secondary Piston to the left compressing the return spring. The Secondary Piston advances until it reaches the far end of the cylinder.

Leakage in the Secondary Circuit

Pressure is not generated in the secondary side of the cylinder. The secondary piston advances until it touches the wall at the end of the cylinder.



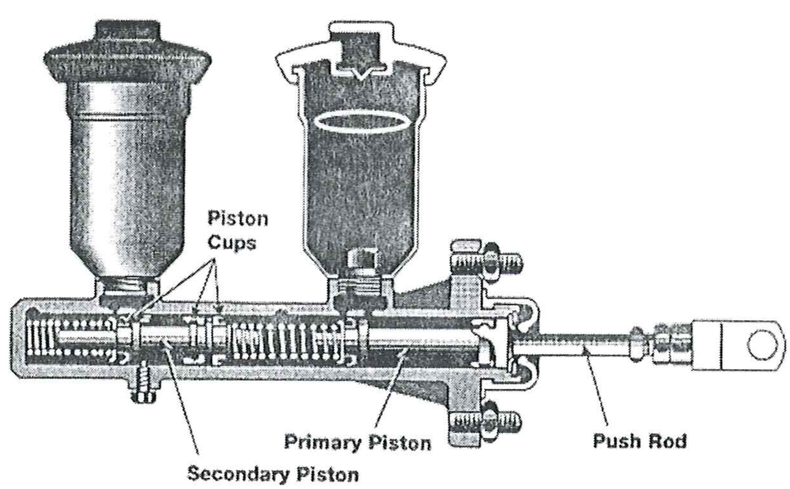
When the Primary Piston is pushed farther to the left, hydraulic pressure increases in the rear (primary) circuit or pressure chamber of the master cylinder. This allows one half of the brake system to operate from the rear Primary Pressure Chamber of the master cylinder.

Separated Reservoir Tank

The master cylinder we have been covering so far has only two piston cups on the Secondary Piston and a single fluid reservoir. A third piston cup is added to the Secondary Piston of master cylinders having separate fluid reservoirs for the primary and secondary chambers.

Dual Reservoir Master Cylinder

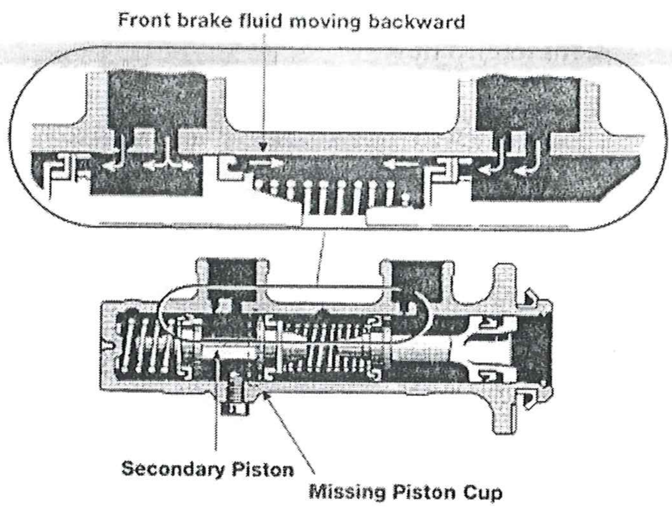
An additional piston cup is added to the secondary piston to seal the secondary cylinder from the primary cylinder.



The third piston cup is located between the front and rear piston cup of the secondary piston and seals the Secondary Chamber from the Primary Chamber. When the brakes are released after brake application, the master cylinder pistons return faster than the fluid can, momentarily creating low pressure (vacuum) in the Primary Chamber. It is the job of the third piston cup to prevent fluid passage between the Secondary Chamber and the Primary Chamber. If the piston cup were missing or worn, fluid passing the third piston cup would fill the Primary Reservoir and deplete the Secondary Reservoir. If left unchecked, the Secondary Reservoir would empty allowing air into the secondary hydraulic circuit.

Role of the Second Piston Cup of the Secondary Piston

Prevents transfer of fluid from the front tank to the rear tank.

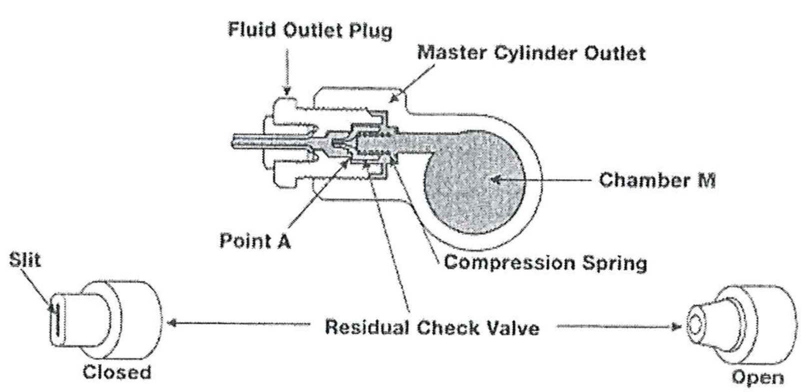


Residual Check Valve

The Residual Check Valve is located in the master cylinder outlet to the rear drum brakes. Its purpose is to maintain about 6 to 8 psi in the hydraulic circuit. When the brakes are released the brake shoe return springs force the wheel cylinder pistons back into the bore. Without the Residual Valve the inertia of fluid returning to the master cylinder may cause a vacuum and allow air to enter the system. In addition to preventing a vacuum, the residual pressure pushes the wheel cylinder cup into contact with the cylinder wall.

Master Cylinder Residual Check Valve

Maintains about 6 to 8 psi in the hydraulic circuit to prevent air from entering.



Portless Master Cylinder

The master cylinder design discussed up to this point has been the conventional compensating port and inlet port type used on most brake systems. A new style master cylinder is used on late model vehicles equipped with ABS and ABS/TRAC (Traction Control).

Initially introduced on the 1991 MR2 and Supra, which were rear wheel drive vehicles, the front piston has a port-less design. The single passage from the reservoir to the secondary piston is non-restrictive. The secondary piston provides a machined passage to the secondary circuit which is controlled with a valve. The valve is spring loaded to seal the piston passage however, a stem attached to the valve holds it from contact with the piston in the "at rest" position. When the brakes are applied the valve closes, sealing the passage and pressure is built in the secondary circuit. The front piston controls pressure to the rear brake calipers.

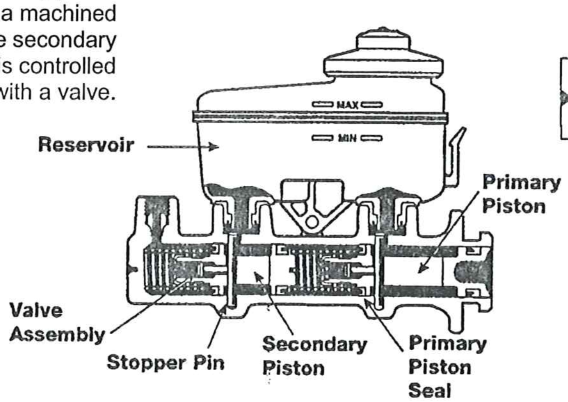
The master cylinder on the 1997 Camry and Avalon incorporates another master cylinder portless design. In this design a spring loaded valve seals the passage in the piston however, in the "at rest" position, a stem attached to the valve contacts the piston retaining pin and unseats the valve.

Three types of master cylinders are available on the 1997 Camry and Avalon depending on the brake system options.

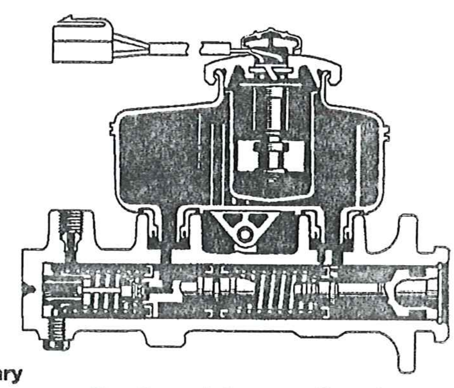
1. Non ABS Brake System - Conventional primary and secondary master cylinder.
2. ABS Brake System - Portless secondary and conventional primary master cylinder.
3. ABS and TRAC Brake System - Portless secondary and Portless primary master cylinder.

Portless Master Cylinder

The single passage from the reservoir to the secondary piston is non restrictive. The secondary piston provides a machined passage to the secondary circuit which is controlled with a valve.



Portless / Portless



Portless / Conventional

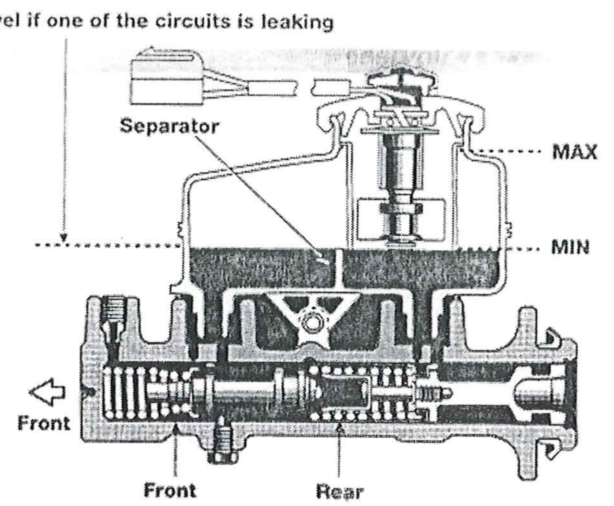
Reservoir Tank

The amount of the brake fluid inside the Reservoir Tank changes during brake operation as Disc Brake Pads wear. A small hole in the reservoir cap connects the reservoir to the atmosphere and prevents pressure fluctuation, which could result in air being drawn into the hydraulic circuit.

A tandem master cylinder having a single reservoir tank has a separator inside that divides the tank into front and rear as shown below. The two-part design of the reservoir ensures that if one circuit fails due to fluid leakage, the other circuit will still be available to stop the vehicle.

Single Fluid Reservoir Tank

A separator inside divides the tank into front and rear parts to ensure that if one circuit fails the other will still have fluid.

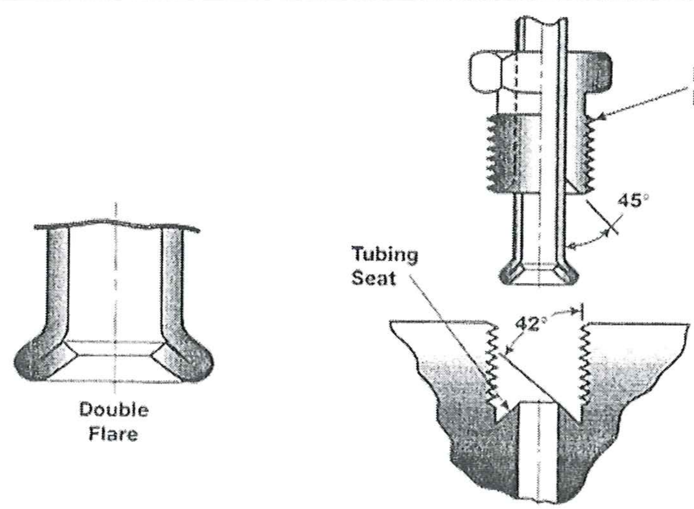


Brake Tubing

Brake hydraulic components are connected by a network of seamless steel tubes and hoses. Brake tubing is made of copper plated steel sheets rolled at least two times and brazed into a single piece and plated with tin and zinc for corrosion resistance. It is produced in different lengths and pre-bent for the specific model applications. Each end is custom flared in a two step process and fitted with a flare nut.

Double Flare Tubing

The tapered seats and double flare tube provide a compression fitting to seal the connection.

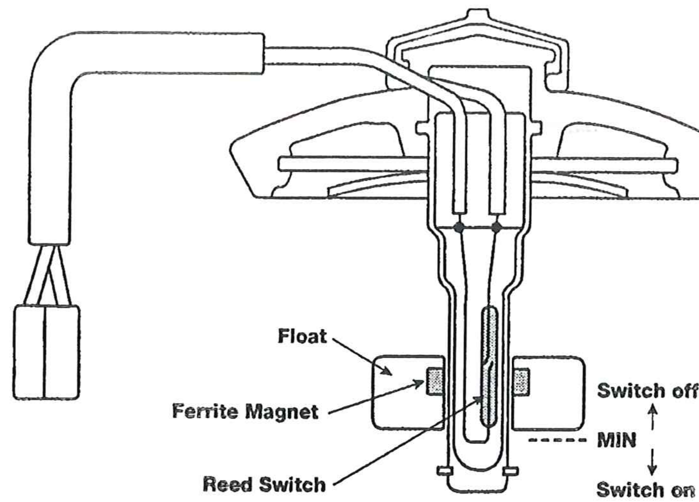


Brake Fluid Level Warning Light Switch

The brake fluid level warning switch is located on the reservoir cap or in some models, is wired within the reservoir body. It normally remains off when there is an appropriate amount of fluid. When the fluid level falls below the minimum level, a magnetic float moves down and causes the switch to close. This activates the red brake warning lamp to warn the driver.

Brake Fluid Level Warning Switch

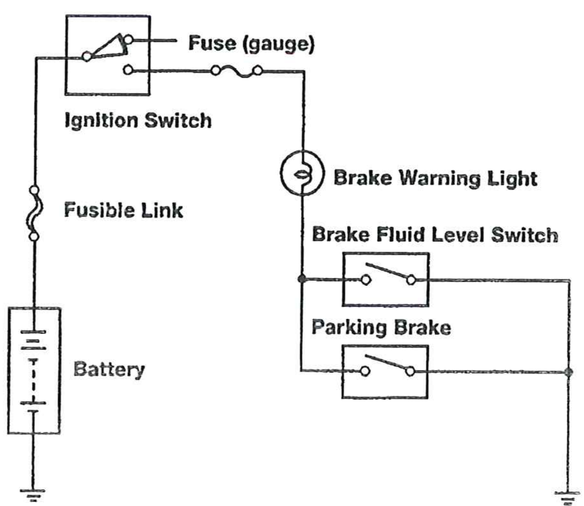
If fluid level falls below the minimum level, a magnetic float moves down and turns the switch on.



A typical brake warning lamp electrical circuit is shown below. It also turns ON when the parking brake is applied.

Brake Warning Light Electrical Circuit

Low brake fluid level or parking brake light turn on.

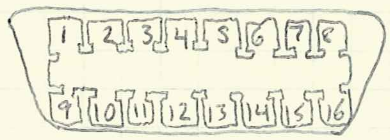


Circuits

On-Board Engine Diagnostics:

OBDII : equipped on all cars built since Jan 1 1996
- three different protocols (rules for format & transmission of data), generally:
  - Chrysler, all European, & most Asian - ISO9141
  - GM cars/light trucks SAE J1850 VPW (variable pulse-width mod.)
  - Fords use SAE J1850 PWM

The Connector:



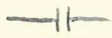
metallic contacts found in each:

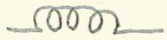
J1850 VPW	2, 4, 5, 16 NOT 10
ISO 9141-2	4, 5, 7, 15, 16
J1850 PWM	2, 4, 5, 10, 16

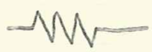
2 J1850 Bus +
4 Chassis Ground
5 Signal ground
6 CAN High (J-2284)
7 ISO 9141-2 K line
10 J1850 Bus
14 CAN low (J2284)
15 ISO 9141-2 L Line
16 Battery Power

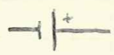
Circuit Diagrams

 Diode

 Capacitor

 inductor

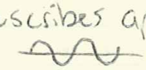
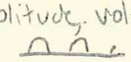
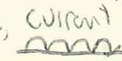
 resistor

 DC voltage source

 AC voltage source

 earth ground

B+ battery positive

Potentiometer: 3 ~~contact~~ terminal resistor w/ sliding contact that forms an adjustable voltage divider
rehostat: a two terminal variable resistor
impedance: a measure of opposition to sinusoidal AC. extends concept of resistance to AC circuits - describes amplitude, voltage, current AND phases
rectifier: converts AC current to DC:  →  or 
phase: initial angle of a sinusoid function at its origin
Hz: # of cycles per second
transformer: device that transfers electrical energy from one circuit to another through inductively coupled conductors
inductor: passive electrical component that can store energy in a magnetic field created by electric current passing through it

M	mega	×	1,000,000
K	kilo	×	1,000
m	mili	×	.001
μ	micro	×	.000001

Using a Multimeter

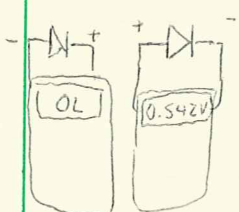
Measure Voltage: open circuit voltage or Pin voltage
1) connect neg. probe to ground @ component ground terminal or known good gnd.
2) connect positive probe to pin to be inspected
3) w/non-auto ranging, use 20v range
- open-circuit measurement tells only if there is connection to B+ NOT how much resistance

Voltage drop: taken dynamically while circuit is in operation
1) turn circuit on.
2) connect neg. & pos. probes to component of circuit in parallel
3) 0 Volt measurement indicates
   a) virtually no resistance
   b) circuit is OFF/open

Ammeter: typically used in starting/charging system inspection, diagnosing parasitic load problems
- parasitic load, or draw: drains the battery while car is parked.
- amperage draw measurement can be taken on known good circuit to compare to circuit in question
- Series type Ammeter
  - built into every DVOM
  - designed to measure > 10A current flow, usually 1A
  - start w/ highest range & work down
- clamp-type ammeters, battery powered & measures current by field around wire

Ohmmeter: measures resistance
- very accurate
1) check for parallel branches & other power sources (be sure it is isolated)
   - do not connect to voltage
2) may have diode checker
   - good quality checks forward bias voltage drop, or what voltage it takes to turn diode ON so current flows *
   - cheap ones just raise voltage on ohmmeter to check for continuity in one direction & not the other

   * silicon diodes on a car require about 0.5V to turn on



3) continuity beep
   - can be set so beeb sounds whenever resistance is less than specified

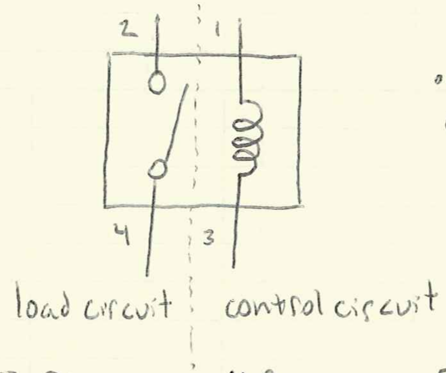
   0Ω means no resistance
   OL means over limit

- never test ECU directly with an ohmmeter. could cause damage & will be inconclusive

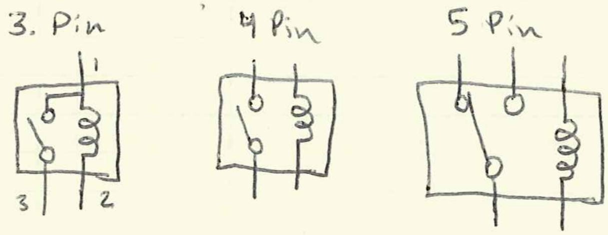
Understanding Relays

Relays: used as remote control switches. - typical vehicle can have 20 or more.
- located throughout entire vehicle
- often grouped with fuses ie. fuse box

- remote control electric switches controlled by another switch
  - allows a small current circuit to control higher current circuit
  - 3pin, 4, 5, 6, single switch or dual switch

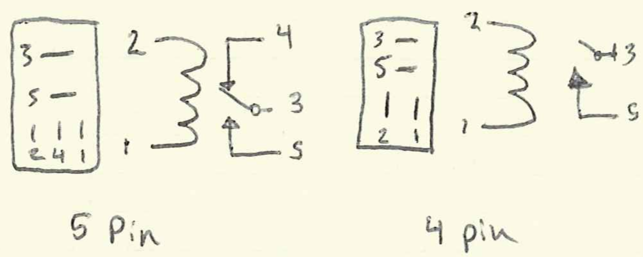


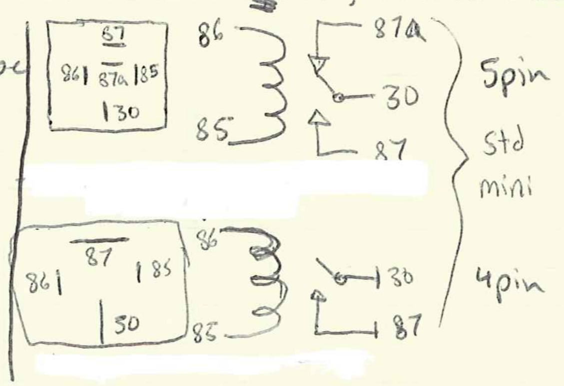
- when relay is energized, control circuit (1 & 3) creates small magnetic field & causes load circuit to close
  - * can be N.O. or N.C.



ISO designation: • 4 & 5 pin designs have standard, mini, & micro size

- standard mini: - 1" square cube
- std. micro: 1"x1" x .5"





- Voltage spikes: when current stops flowing through control circuit, magnetic field collapses around the coil & sends a positive spike (200+V) in opposite direction. (Back towards positive terminal.
  - some relays have built in voltage suppression. this is a high-ohm resistor, diode, or capacitor
    - relays are clearly marked usually if they have voltage suppression
  - relays can have de-spiking diodes & spiking resistors

Co-op / Intern Final Evaluation Form
TOYOTA

At TOYOTA, our goal is to provide our Co-op / Intern students with meaningful work experiences. In an effort to accomplish this goal, we ask that you please complete the following questions with thought, concern, and sincerity. The co-op should complete the student section with what he/she has done/accomplished in each appraisal factor and then give to his/her supervisor/mentor to complete. Supervisors should complete the Final Evaluation during the Co-op/Intern's last week of their assignment. It is important that the Co-op/Intern be given this feedback during a meeting between both parties so that the Supervisor can clarify any questions the Co-op/Intern may have regarding their final evaluation.

Student Name:	David Malawey	Division/ Section:	TEMA stamping equipment ~~Mentor:~~ Supervisor: Douglas B. Lefler
Date:	7/27/09	Manager:	Scott Buchanan

Rating Explanations:

Meets Expectations- Capabilities demonstrated are appropriate for the job. Meets the standards for the job

Needs Improvement- Capabilities demonstrated show a partial understanding of the job. Needs development.

Below expectations- Capabilities demonstrated do not meet the minimum standard for the job. Needs immediate attention.

Performance Appraisal Factor	Appraisal Factor Definition	Student Section	Meets Expectations	Needs Improvement	Below Expectations	Supervisor Section
		Examples of work, activities or projects co-op has completed exhibiting this topic	Place an x under the column the co-ops performance falls under.			Comments on co-ops current performance
Attendance and punctuality	Arrives for work/meetings on time and gives proper notice when unable to be on time.	10A safety device checkout	✓			Always on time
Takes initiative	Accomplishes tasks/projects with limited supervision and seeks out work when not busy.	working in Powertrain 1week	✓			Always looking for work when not busy.
Demonstrates flexibility	Shows ability to adjust to non-routine assignments.	Traveling to TMMI w/ Greg Curlin	✓			Projects varied greatly.
Promotes respect in workplace	Presents a positive attitude and interacts with co-workers respectfully.	building parts mounts for TEMA device lab	✓			Got along good with everyone
Demonstrates problem solving/resolution skills	Identifies issues and problems. Gathers and interprets information and generates alternatives. Chooses appropriate action, commits to action and involves others.	10A sound barrier project Learning tonnage monitoring systems	✓			
Approaches tasks with a sense of urgency	Identifies which tasks/projects are most important and completes them timely and correctly.	Seeking LOTO training, researching highlight oil for parts inspection	✓			
Displays attention to detail	Though in accomplishing a task with concern for all details involved no matter how small.	Creating wire labels for TABC safety upgrade complete parts tracking for machine upgrades	✓			
Willing to accept responsibility	Shows accountability for their work and actions.	initiating meetings / monthly reviews	✓			
Effective communication skills	Transfers information to others in appropriate manners.	working with Bluegrass Safety, General Rubber, IES, & HELM instruments	✓			Good verbal/written skills
Effective time/project management skills	Plans, organizes and manages resources to successfully complete a project on time.	disassemble subpanels & ship parts to TABC for installation - short notice	✓			
	Totals: Add number of checks for each rating, the highest total will be the overall rating		✓			**Overall Rating:**

STUDENT SECTION: Any additional comments, questions, or suggestions:

supervisors should have more notice when co-ops will be hired to their dept.

SUPERVISOR SECTION: Any additional comments, questions, or suggestions:

Signatures

Co-op / Intern	AM or Manager	Mentor	
David Malawey 7/27/09	Doug B. Lefler 7/27/09		*Please note that your signature doesn't necessarily mean that you agree with this review, but rather it was discussed by both you and your immediate supervisor.*

Manager/Supervisor: Please complete the below section following the performance discussion with the co-op and after the co-op has signed above.

Is this person a good fit for Toyota? Circle Yes No If no, please explain why.

Is this person a good fit for your department? Circle Yes No If no, please explain why.

Is this person a good fit for another department? Circle Yes No If no, please explain why.

Once Completed: Manager/Supervisor must return thesurvey to the Co-op/Intern Coordinator.