Fuel/Air Theory Overview

A. Fuel Composition

B. Air/Fuel Mixture

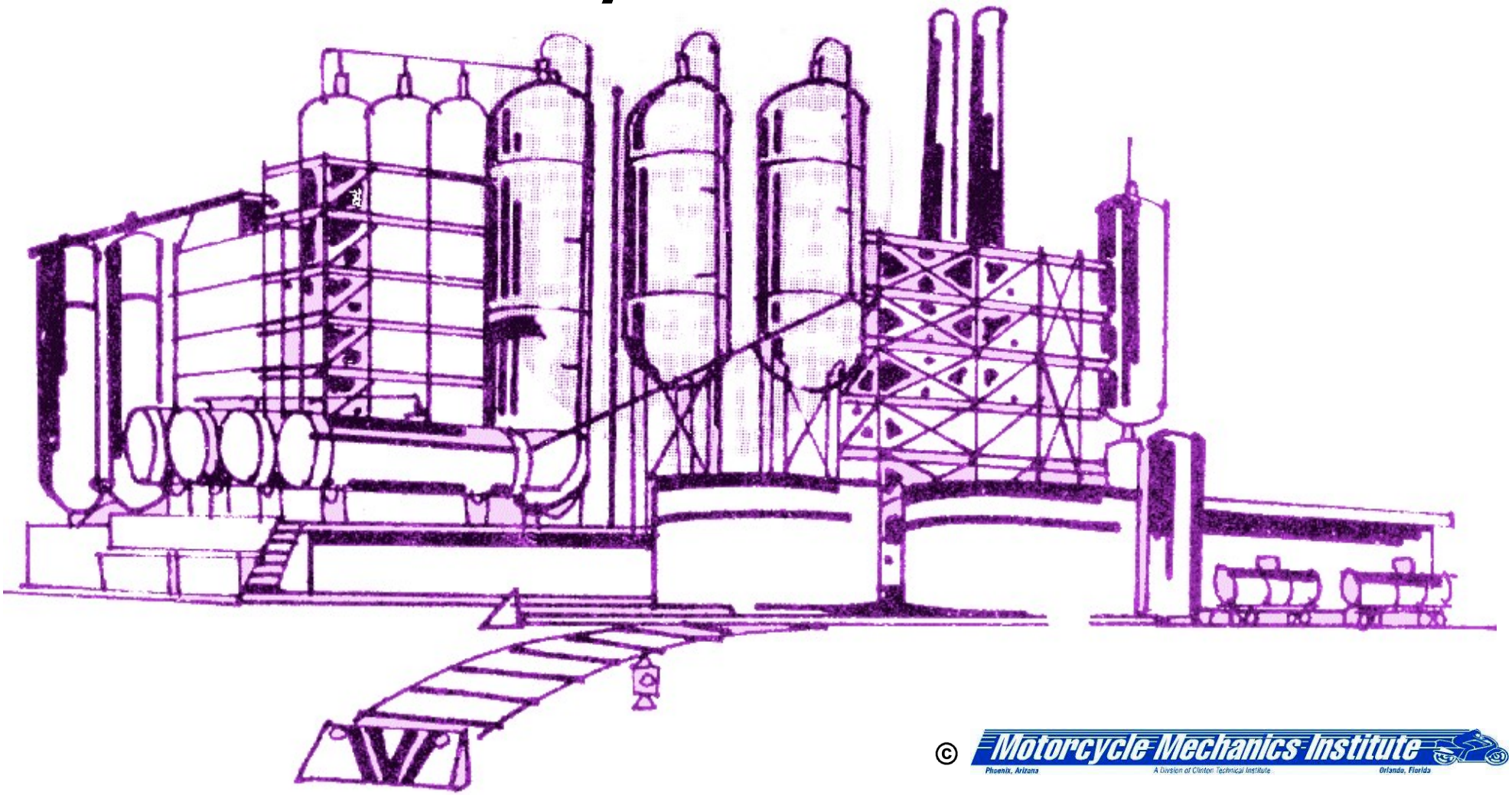
C. Air Density

Fuel and Air Theory

I. Fuel Composition

A. Derivative of crude oil (fossilized material)

1. Just like motor oil
2. Fractionally distilled



(Fuel Composition, cont.)

- **B. Octane**
  1. **The fuel's resistance to detonation**
  2. **Also called "knock" rating**
  3. **Conditions affecting detonation**
     - **a. Octane**
     - **b. Compression ratio**
     - **c. Fuel mixture**
     - **d. Engine loading**
     - **e. Ignition timing**
     - **f. Air temperature**
     - **g. Altitude**
     - **h. Humidity**

(Fuel Composition, continued)

C. The octane rating system
   1. Heptane
      a. Reference fuel (laboratory chemical) representing the upper limits of burnability and the lower limits of compressibility
      b. I.e. this is as burnable as fuel gets
      c. "O" octane
   2. Iso-octane
      a. Reference fuel (laboratory chemical) representing the upper limits of compressibility and the lower limits of burnability
      b. I.e. this is as compressible as fuel gets
      c. "100" octane

(The octane rating system, continued)

3. Testbed engines with variable compression, ignition timing and fuel strength are used
4. Tested fuels are rated according to how they behave compared with the reference fuels
   a. A 90-octane gasoline is one which behaves like a mixture of 10% heptane and 90% iso-octane
   b. Gasolines rated over 100 are ones which still exhibit 100-octane properties after the compression and/or ignition timing is increased, and thus get 100+ numbers

(The octane rating system, continued)

5. Pump octane
   a. Test methods were inconsistent until a compromise between the two prevailing methods was reached
      (1) "Research" octane = cruise, light load
      (2) "Motor" octane = acceleration, wide open
   b. In 1928, the Pump Octane rating appeared

$$P = \frac{R + M}{2}$$

(Fuel Composition, continued)

D. Types of fuel

1. Gasoline

a. Octane formerly enhanced with Tetraethyl lead

(1) Toxicity

(2) Damaged catalytic converters

b. During 70s, benzene, toluene and other chemicals substituted

c. Later, alkyl hydrocarbons substituted

d. Most unleaded gasolines' octane now improved by oxygenates

(Types of fuel, continued)

2. Oxygenated gasoline ("gasohol")
   a. Contains oxygenates (chemicals which increase the oxygen content of the fuel)
   b. Permits more hydrogen-carbon molecules to combine chemically during combustion
   c. Used because causes carbon monoxide exhaust emissions to decrease
   d. Mixture is chemically leaner

(Oxygenated gasoline, included)

e. Oxygenates used in oxygenated gasoline

(1) Ethanol

(a) Produced by fermentation

(b) OEMs discourage mixtures above 10%

(2) Methanol

(a) A distilled product

(b) OEMs discourage mixtures above 5%

(3) MTBE (Methyl Tertiary Butyl Ether)

(a) A distilled product

(b) OEMs discourage mixtures above 15%

(c) Most commonly used nationwide, seasonal in some areas

(Types of fuel, continued)

3. Reformulated gasoline (RFG)
    a. Based on different sets of hydrocarbons than those in conventional gasoline
    b. Results in decreased HC emissions
    c. Other emissions are <u>increased</u>, however
    d. Most benefit when used in older, non-EMS (Engine Management System) engines
    e. Still being studied

(Types of fuel, continued)

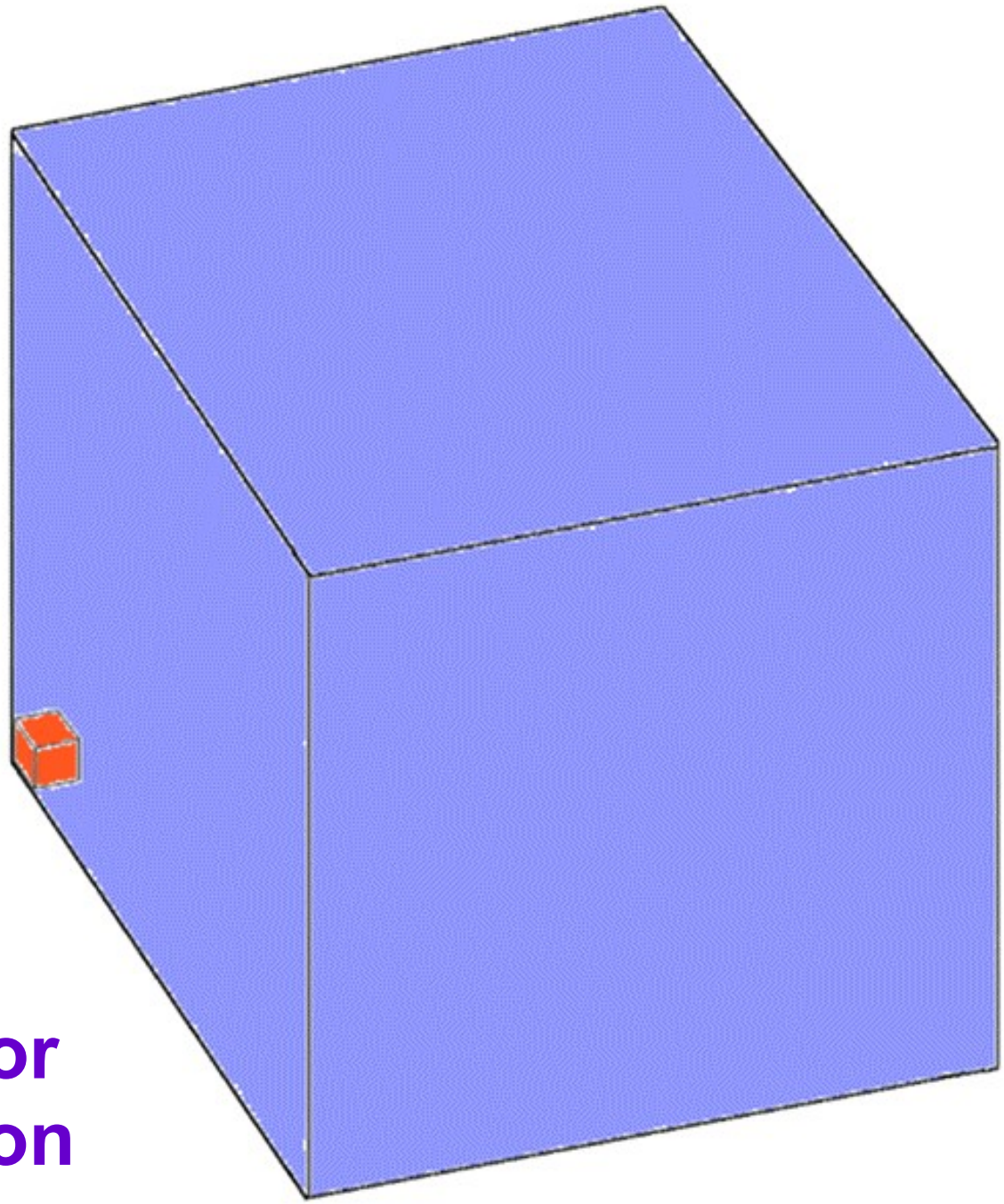
4. Alcohol (straight)
   a. Not recommended by any manufacturer
   b. Pros
      (1) 15-25% increase in power
      (2) Naturally high in octane (through oxygenation)
      (3) Internal cooling effect
   c. Cons
      (1) Hygroscopic
      (2) Deteriorates synthetic materials
      (3) Lacks the lubricating qualities of gasoline
      (4) Reacts quickly with aluminum
      (5) Hard to vaporize

(Fuel and Air Theory continued)

II. Air/Fuel Mixture

A. Ratio

1. By weight
2. Example:
   15:1
   means
   15 parts
   air to 1
   part fuel,
   by weight



Shown by volume for purpose of illustration

(Ratio, continued)

3. Chemically ideal mixture is 14.7:1
   a. Best utilization of all molecules
   b. Called "Stoichiometric"
   c. 16:1 is leaner
   d. 12:1 is richer

Stoichiometric (Gr) = "Bullseye Measurement"

(Air/Fuel Mixture, continued)

B. Actual working mixtures
   1. The best mixture at any given time is dependent on
      a. Rpm
      b. Intake speed
      c. Air density
      d. Temperature
      e. Engine load
   2. Therefore, the fuel delivery system must be flexible, and provide varying mixtures to suit different conditions, using
      a. The carburetor's many circuits
      b. The fuel injection system's computer control

(Air/Fuel Mixture, continued)

C. Conditions

1. Cold starting

a. Requires the richest mixture, about 8:1

b. Cold engine offers minimal vaporization of the liquid fuel

c. More fuel must be present to get enough vaporized to start the engine

(Conditions, continued)

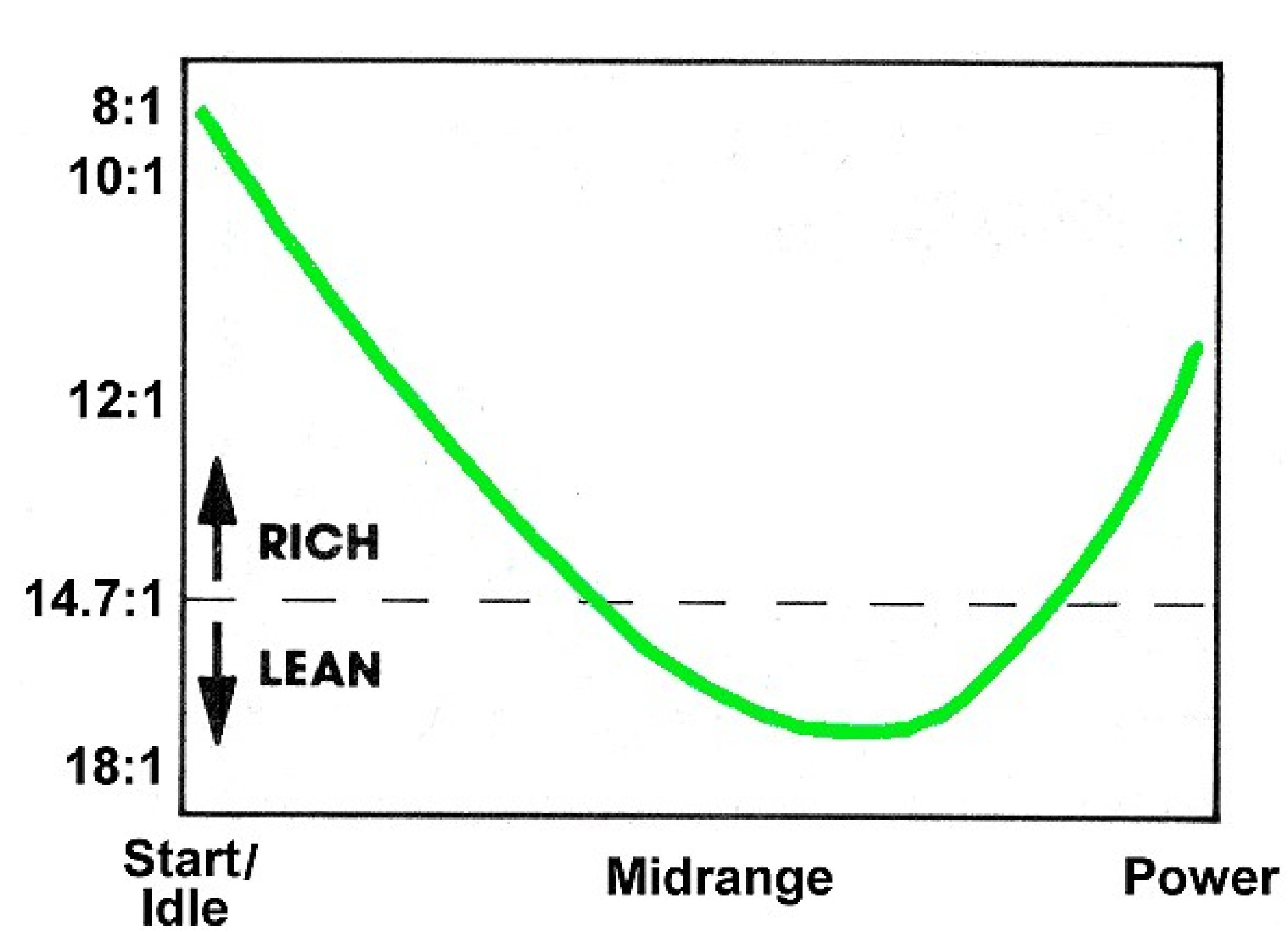
2. Idling
   a. Requires a slightly less rich mixture of about 10:1
   b. Low intake air speed results in reduced atomization and consequently poor combustion

(Conditions, continued)

3. Midrange (cruise)
   a. Requires the leanest of all mixtures, or about 16:1
   b. Small throttle opening combined with moderate rpm result in high intake velocity, which together with light engine load results in high combustion efficiency

(Conditions, continued)

4. Power (acceleration)
   a. Requires a richer mixture of about 12:1
   b. High power production raises heat, some of the fuel is needed to cool the engine



(Fuel and Air Theory, cont.)

III. Air Density

A. Amount of oxygen in a given space

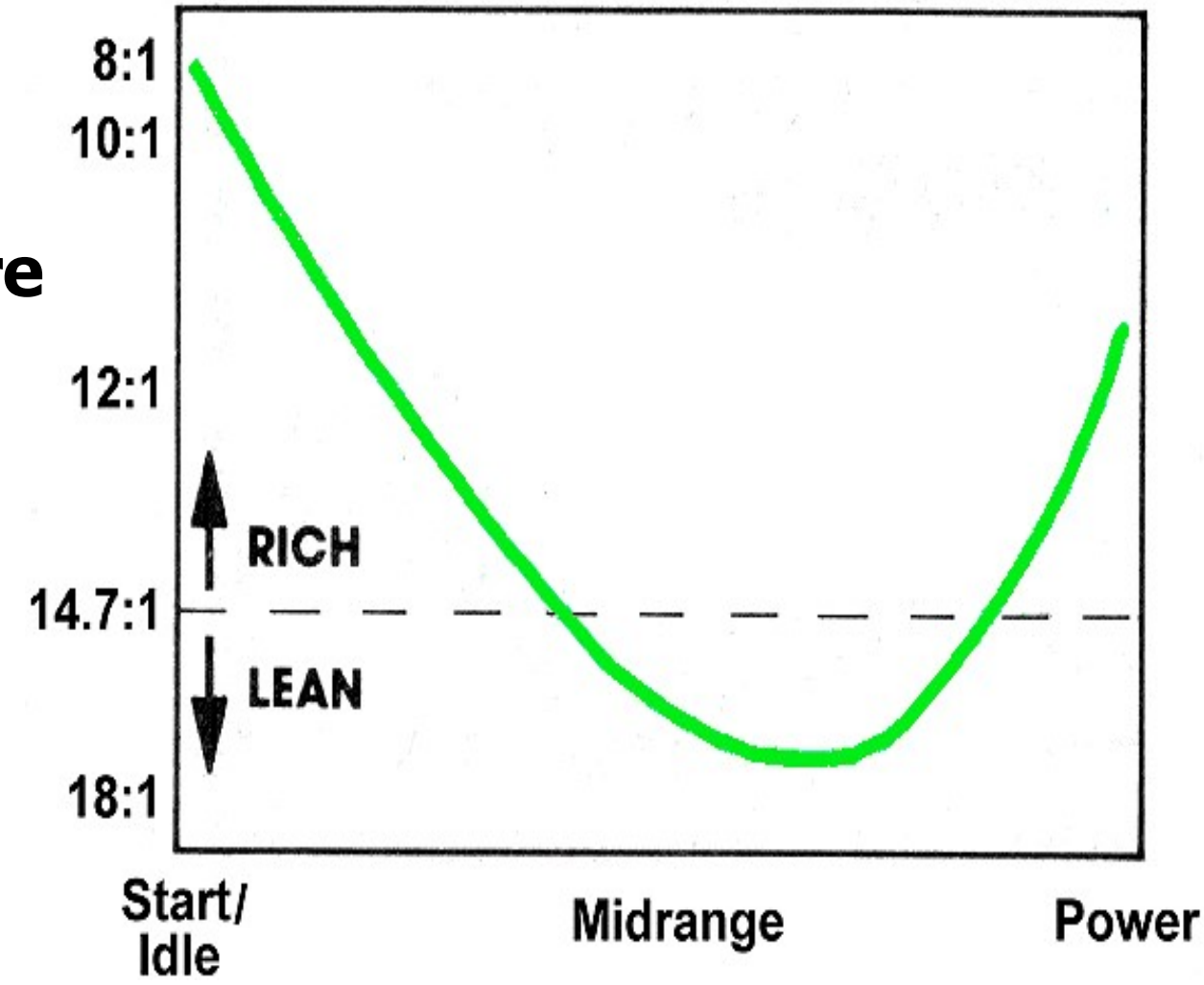
1. Increases
   a. When altitude decreases
   b. When temperature decreases
   c. When humidity decreases
   d. Leans out fuel delivery
2. Decreases
   a. When altitude increases
   b. When temperature increases
   c. When humidity increases
   d. Richens fuel delivery

Fuel/Air Theory Review

A. Fuel Composition
   1. Octane
   2. Types

B. Air/Fuel Mixture
   1. Ratio
   2. Working mixtures
   3. Conditions

C. Air Density



Fuel System Support Components Overview

A. Fuel Related

B. Air Related

Courtesy
Harley-Davidson
Motor Co.

Fuel System Support Components

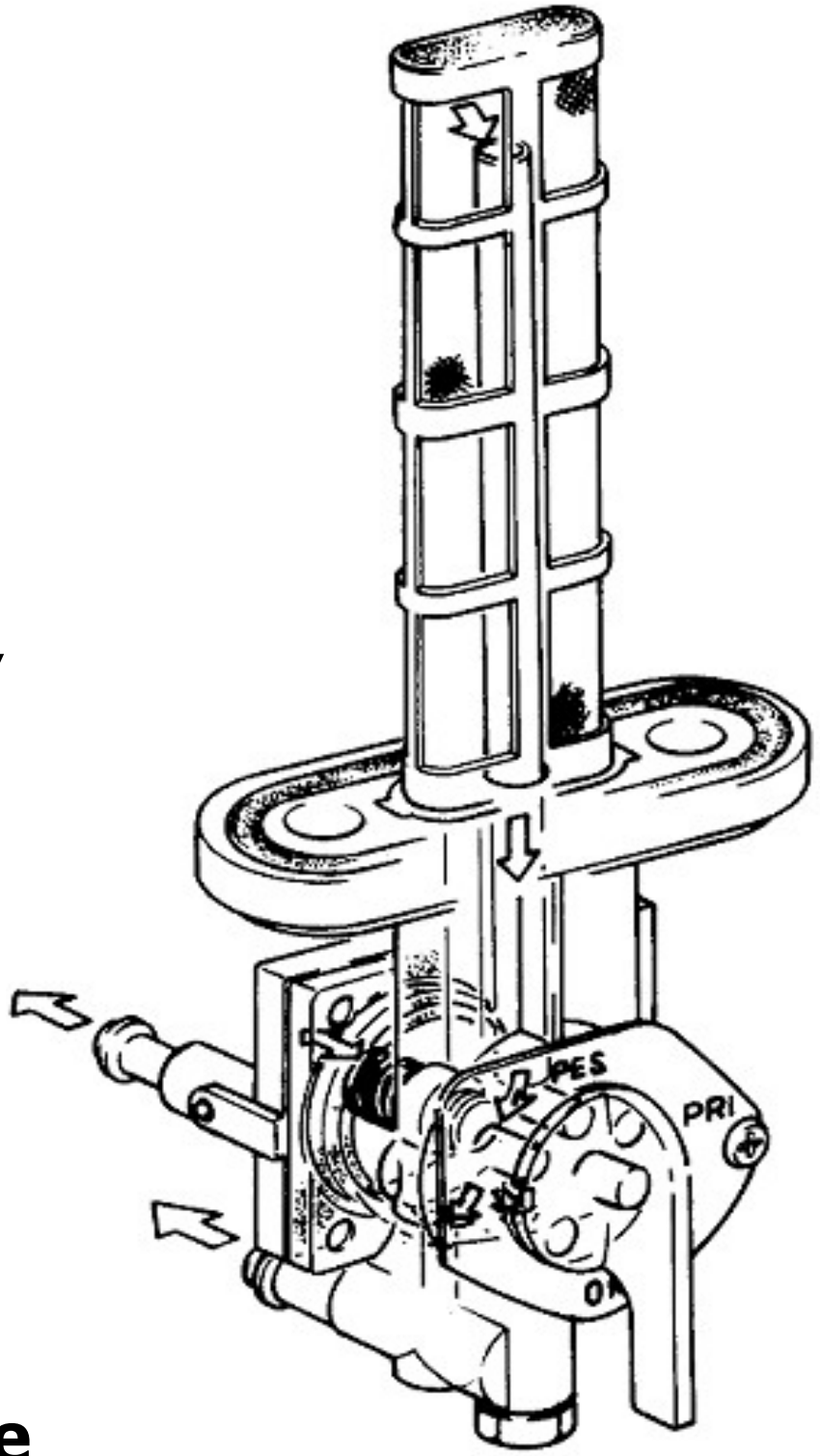
I. Fuel Related

A. Fuel tank

1. Stores fuel
2. Vented
   a. *Boyle's Law:* for fuel to exit, air must enter
   b. Evap systems in California: fuel tank vents into charcoal canister
3. Some have fuel gauge sending unit

(Fuel Related, continued)

- **B. Fuel valve**
  1. **On/off valve**
     - **a. Enables easy removal of fuel tank for servicing**
     - **b. Provides "reserve" (RES) function**
     - **c. Many are automatic**
  2. **Traditional name: "petcock"**
  3. **May or may not be at fuel tank**
  4. **May be more than one**



(Fuel valve, cont.)

5. Types
   a. Manual
      1) On
      2) Off
      3) Reserve (RES)
   b. Vacuum
      1) Opens when engine is running and closes when engine is turned off
      2) On position: normal flow
      3) Reserve (RES) position: to access reserve fuel supply
      4) Prime (PRI) position: to make fuel flow even though engine is not running
   c. Electric
   d. Vacuum with electric assist

(Fuel Related, continued)

- C. Fuel line
  - 1. Often neoprene/hypalon for durability
  - 2. Routing very important
- D. Fuel filter
  - 1. May be found
    - a. As part of fuel valve
    - b. Near the fuel pump
- E. Fuel pump
  - 1. Applications
    - a. Tank too low to provide adequate pressure to carburetors
    - b. Fuel injection systems
  - 2. Types
    - a. Mechanical
    - b. Electric
    - c. Vacuum

(Fuel System Support Components, continued)

II. Air Related

A. Throttle

1. Often dual cable
2. Free-play important

B. Manifold

1. Conduit and seal between intake and engine
2. Part of tuned length

C. Air filter

1. Types
   a. Paper
   b. Foam
   c. Gauze

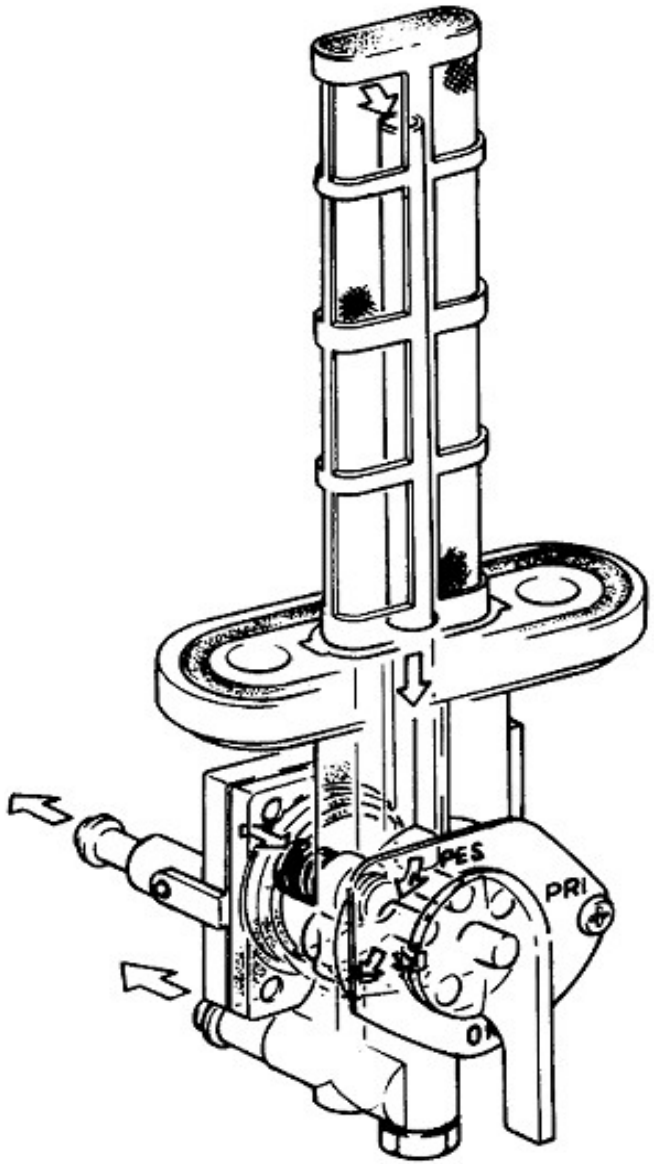
(Types, cont.)

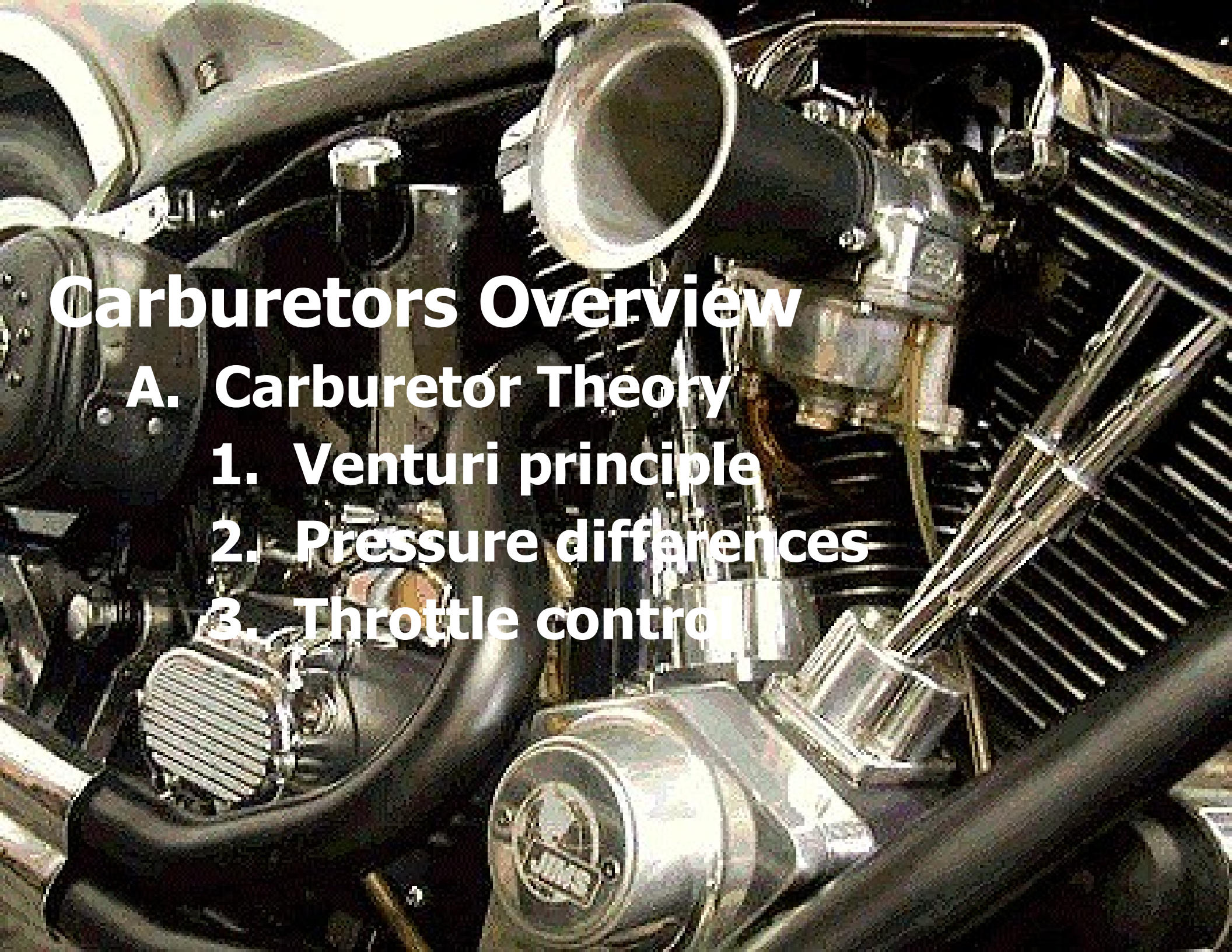
K&N
Air Filter

Fuel System Support Components Review

A. Fuel Related

B. Air Related

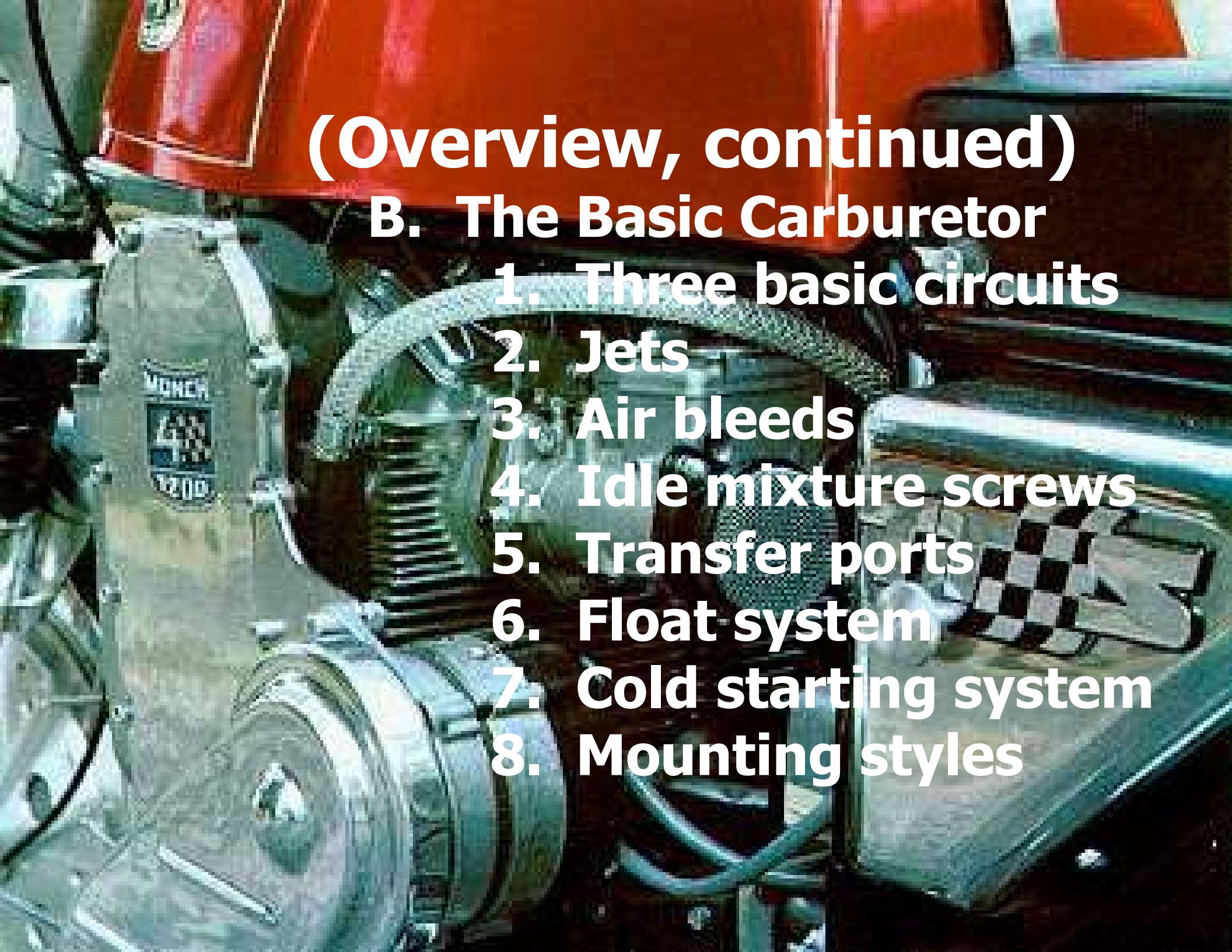




Carburetors Overview

A. Carburetor Theory

1. Venturi principle
2. Pressure differences
3. Throttle control



(Overview, continued)

B. The Basic Carburetor

1. Three basic circuits
2. Jets
3. Air bleeds
4. Idle mixture screws
5. Transfer ports
6. Float system
7. Cold starting system
8. Mounting styles

(Overview, continued)

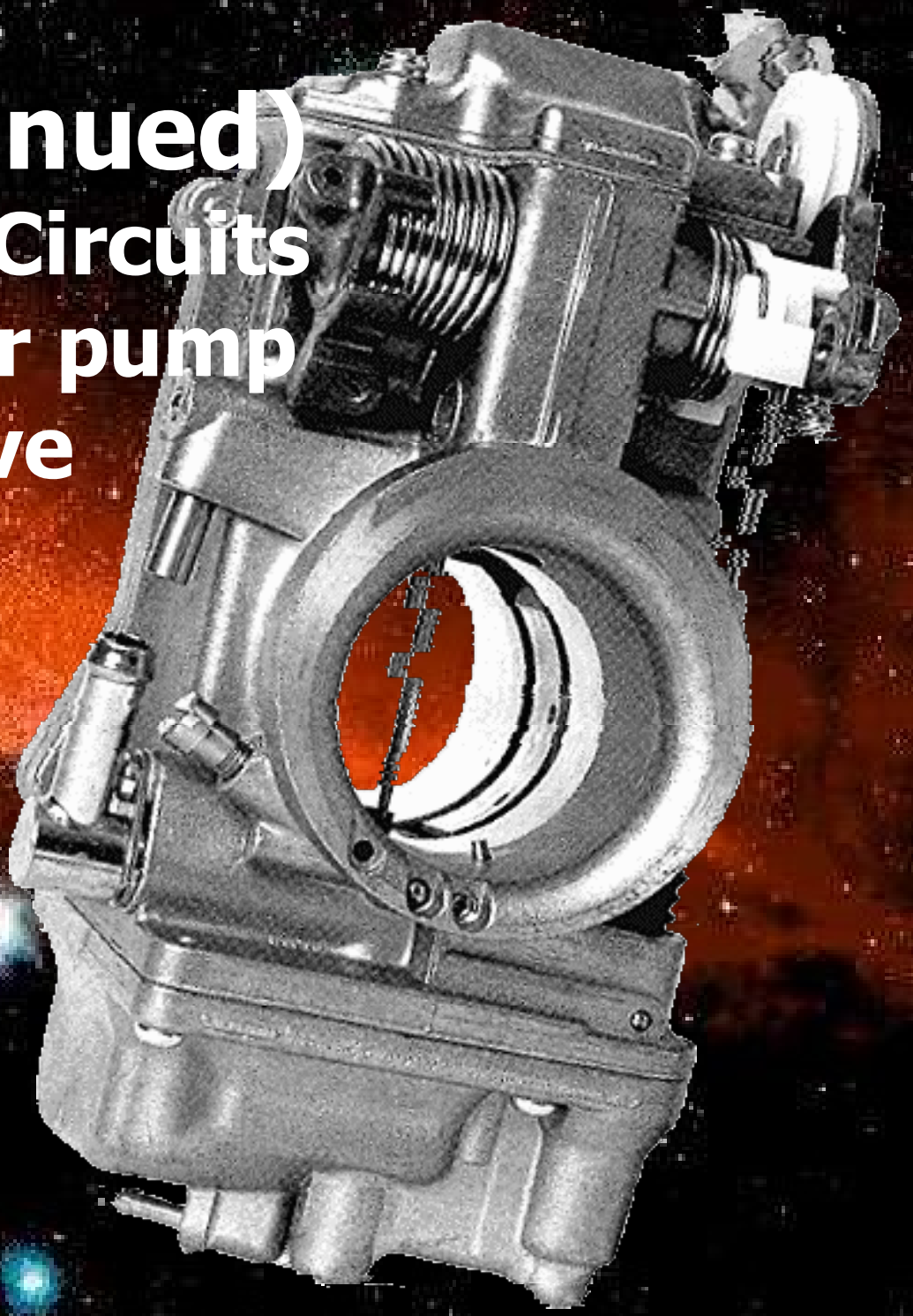
C. Carburetor Types

1. Fixed venturi
2. Mechanical slide
3. Constant velocity

(Overview, continued)

D. Supplemental Circuits

1. Accelerator pump
2. Air cut valve
3. Powerjet



I. Carburetor Theory

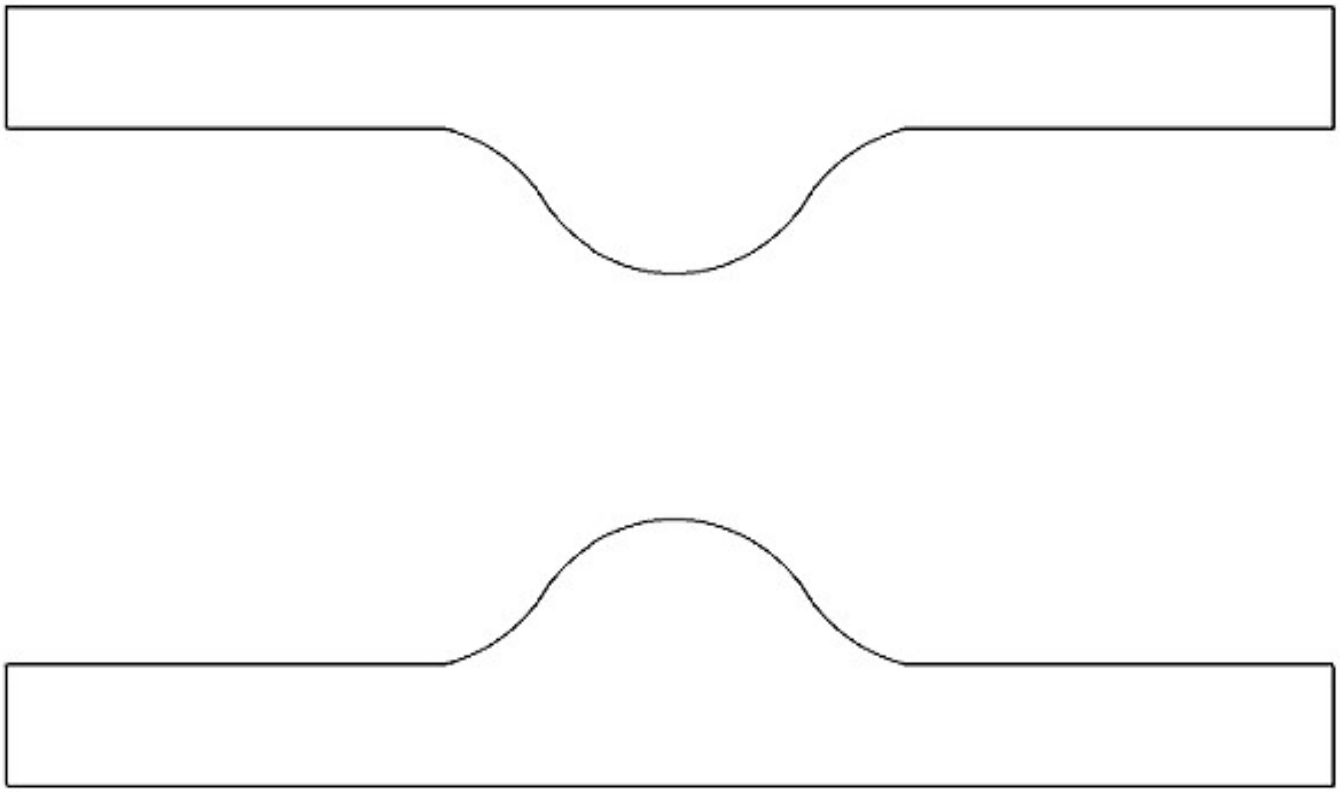
A. Purposes of the carburetor

1. Combine air and fuel
   a. "Carburet" = saturate (intake air) with carbon (hydrocarbons)
   b. Atomized = liquid drops suspended in air
2. Make mixture available at varying ratios to suit various engine conditions
3. Control airflow into the engine to control engine rpm

(Carburetor Theory, continued)

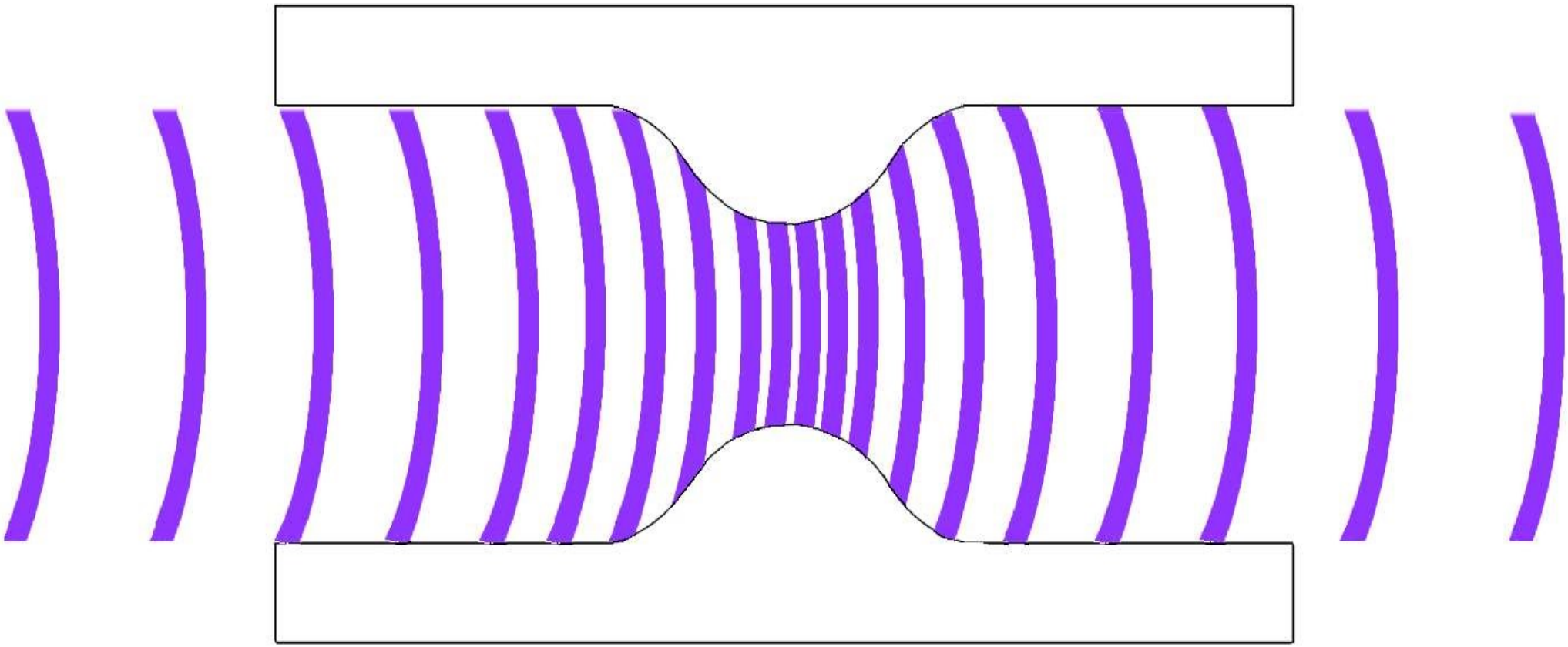
B. The venturi principle

1. A venturi is a restriction inside a tube



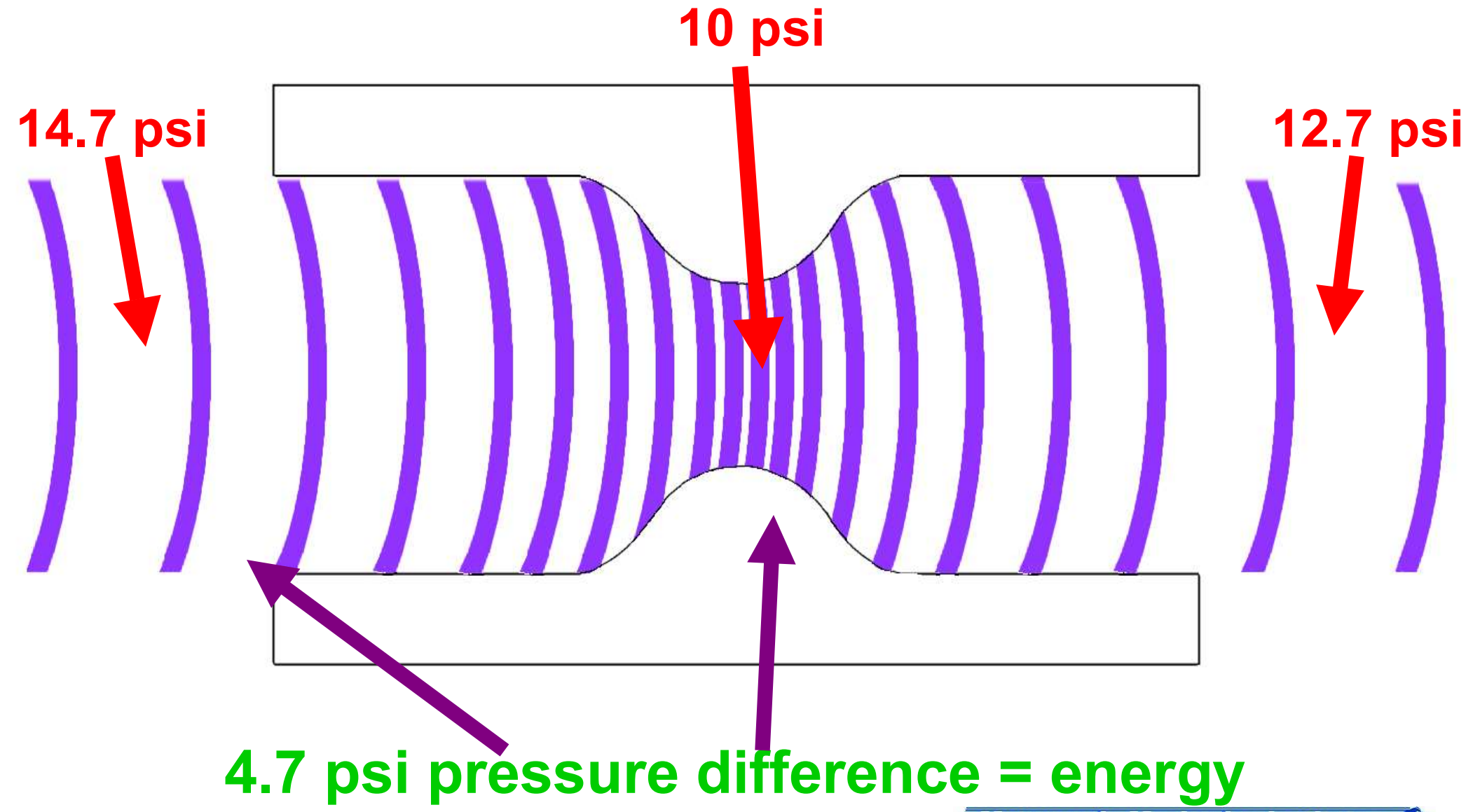
(The venturi principle, continued)

2. **Air moving through the restricted area (venturi) speeds up at that point**



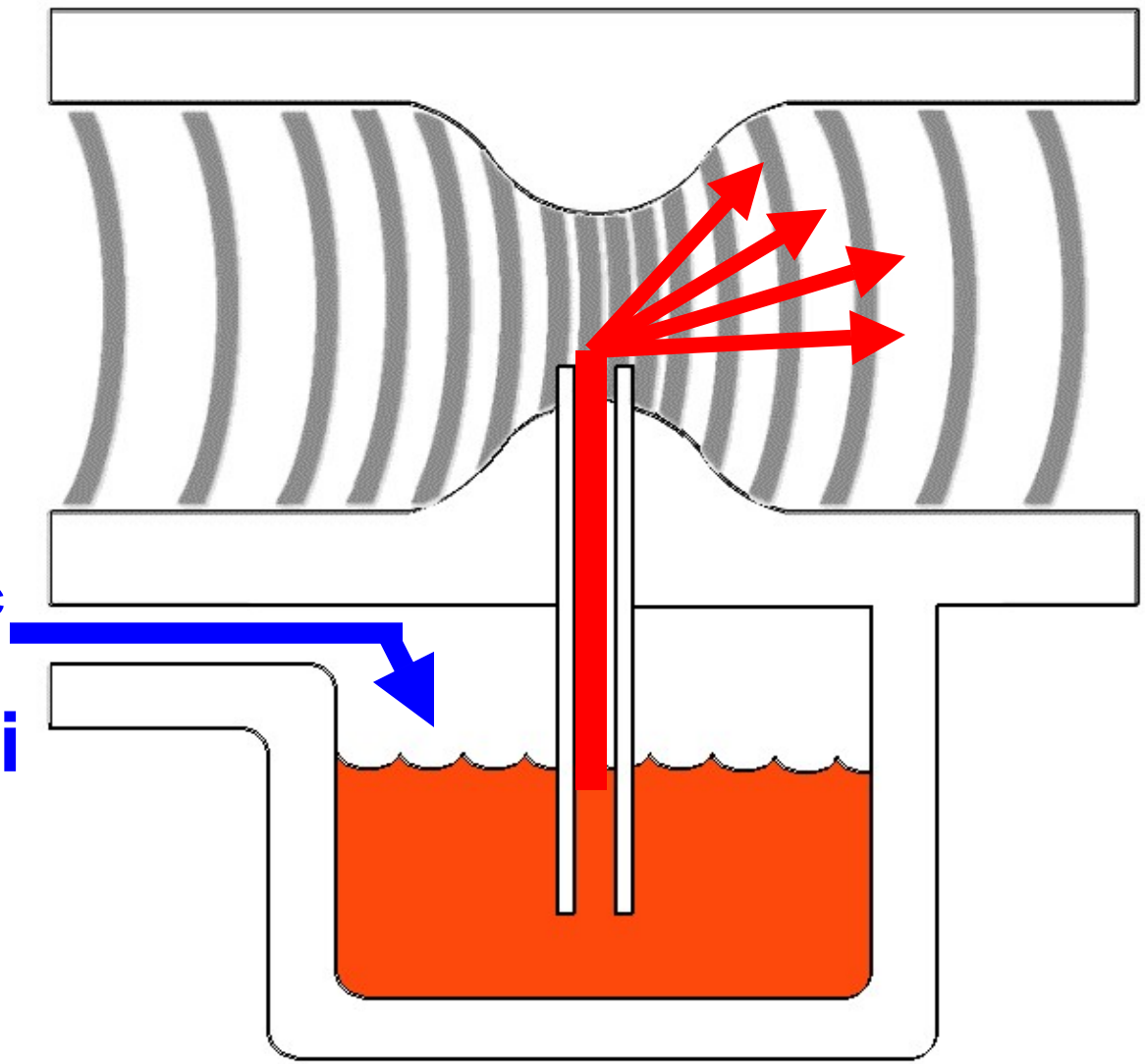
(The venturi principle, continued)

3. **Where the air speeds up, its pressure drops**
4. **This drop in pressure is energy**



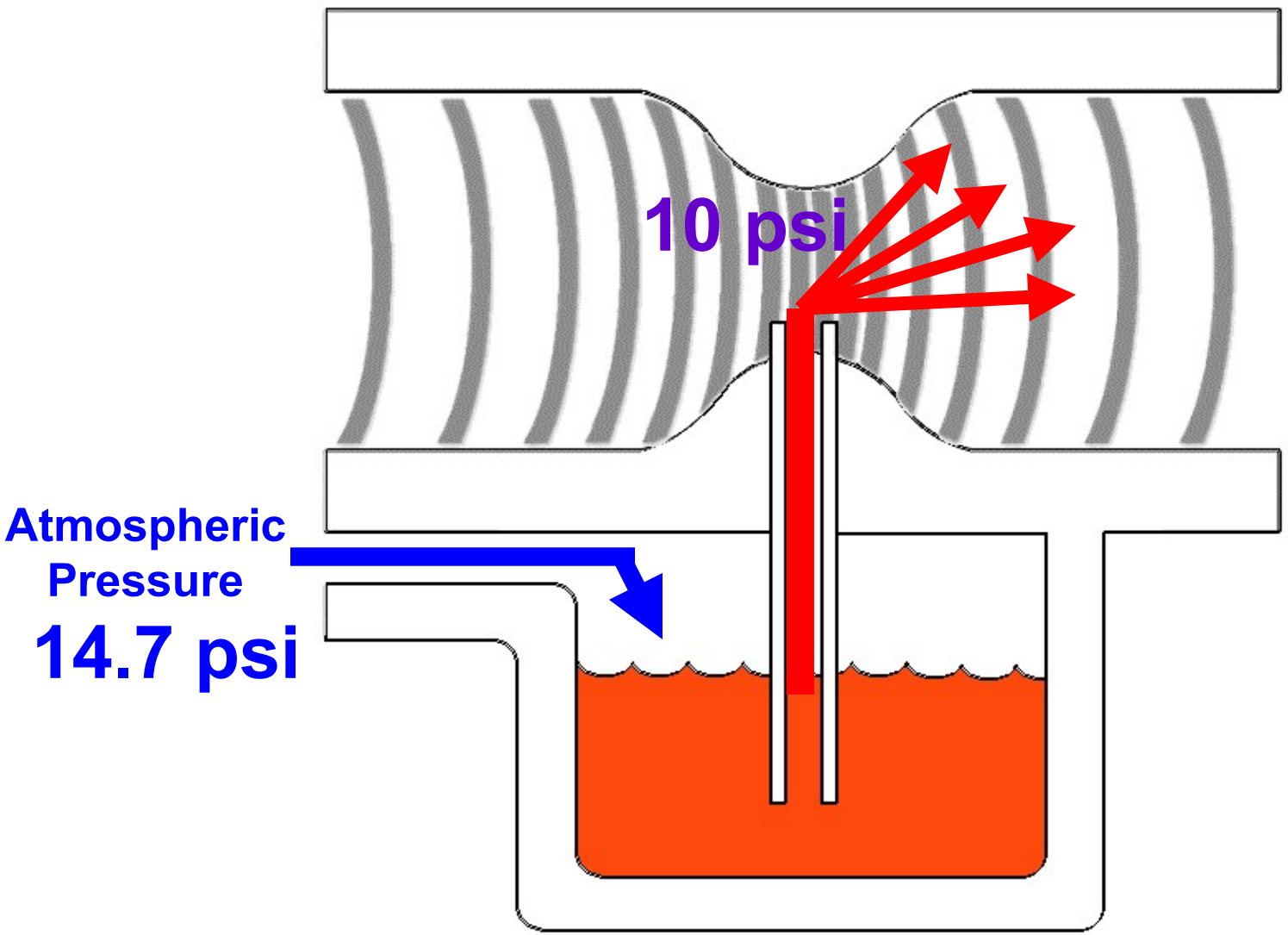
C. Pressure differences

1. Tube suspended from the low pressure area into the higher pressure fuel results in fuel being pushed up the tube



(Pressure differences, continued)

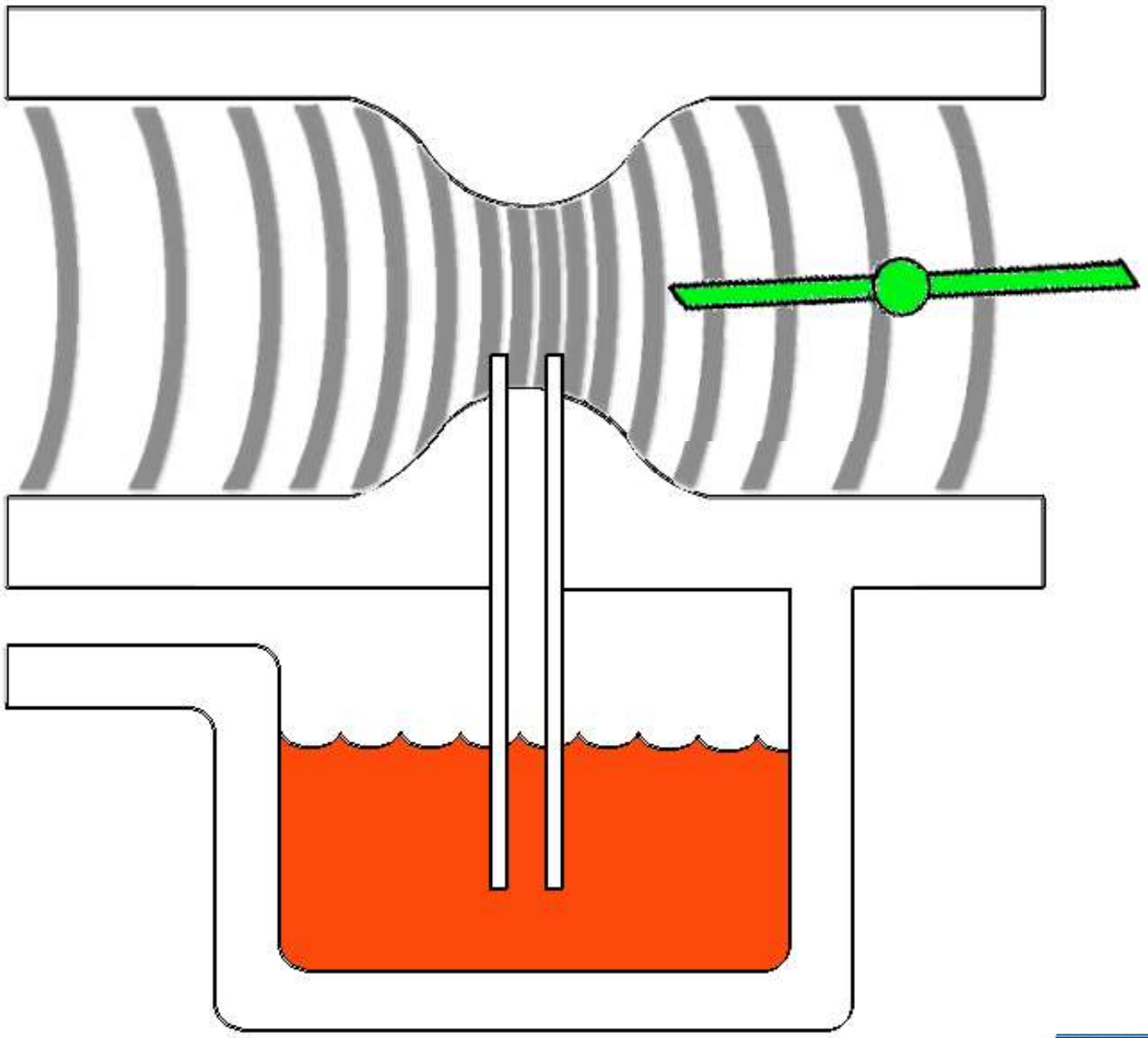
2. **The pressure difference between the atmosphere and the venturi is what moves the fuel**



4.7 psi difference moves the fuel

D. Throttle control

1. The throttle controls airflow into the engine
   a. Controls rpm
   b. Determines venturi velocity



II. The Basic Carburetor

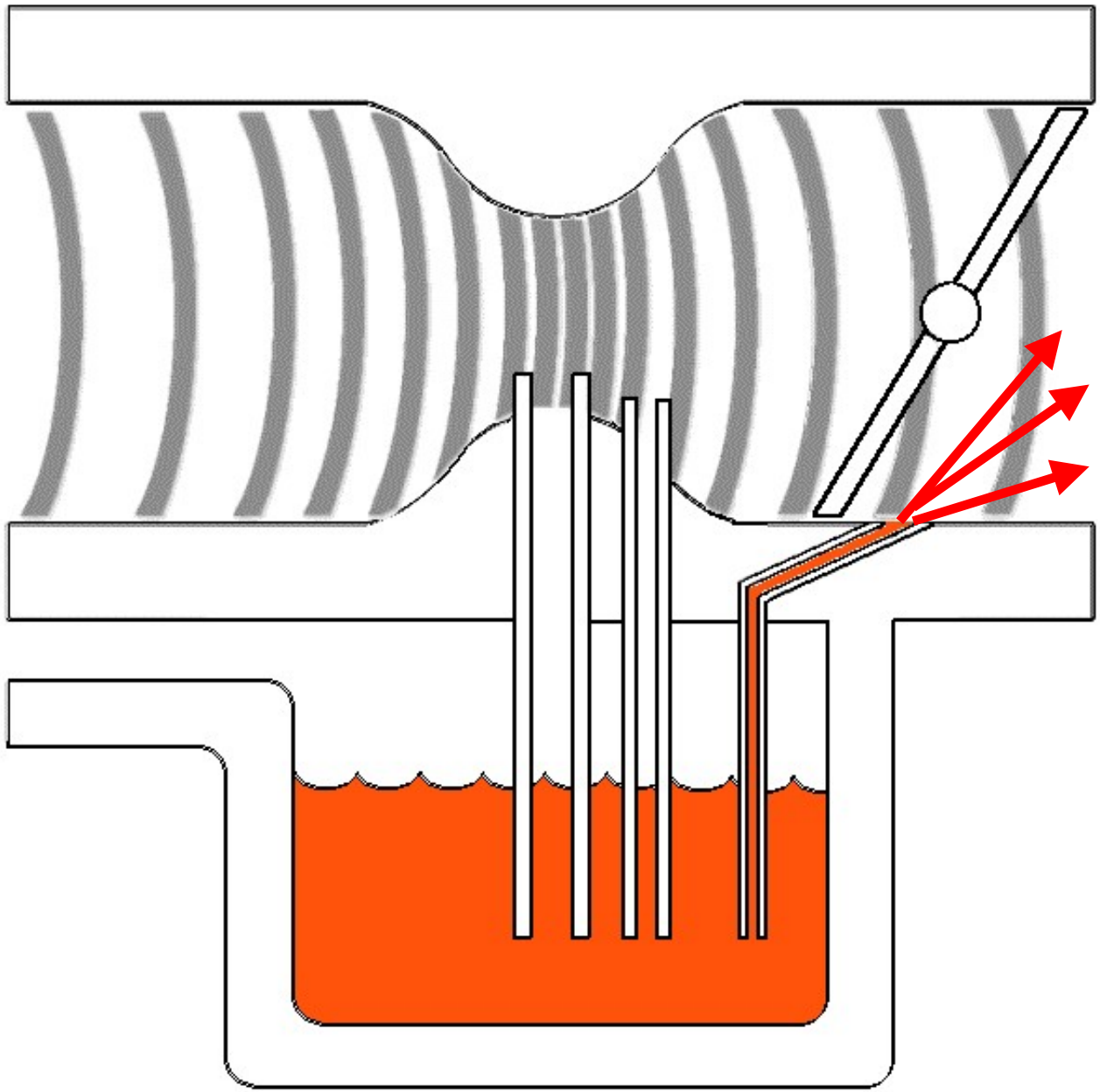
A. 3 Basic Circuits

1. Idle

a. Exposed to the engine even with throttle at rest

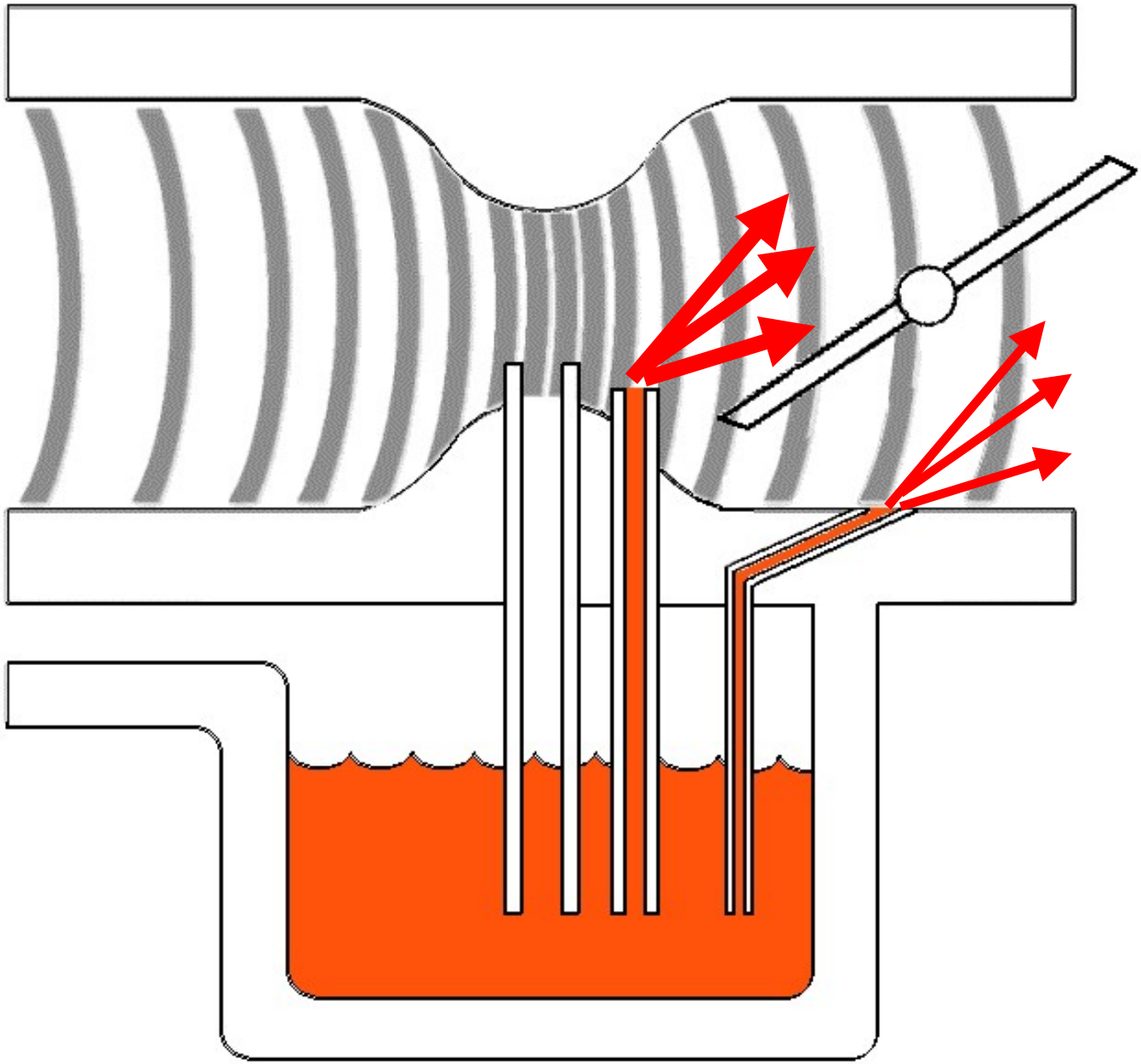
b. Flowing whenever the engine is running

c. Also called "pilot" or "slow" circuit



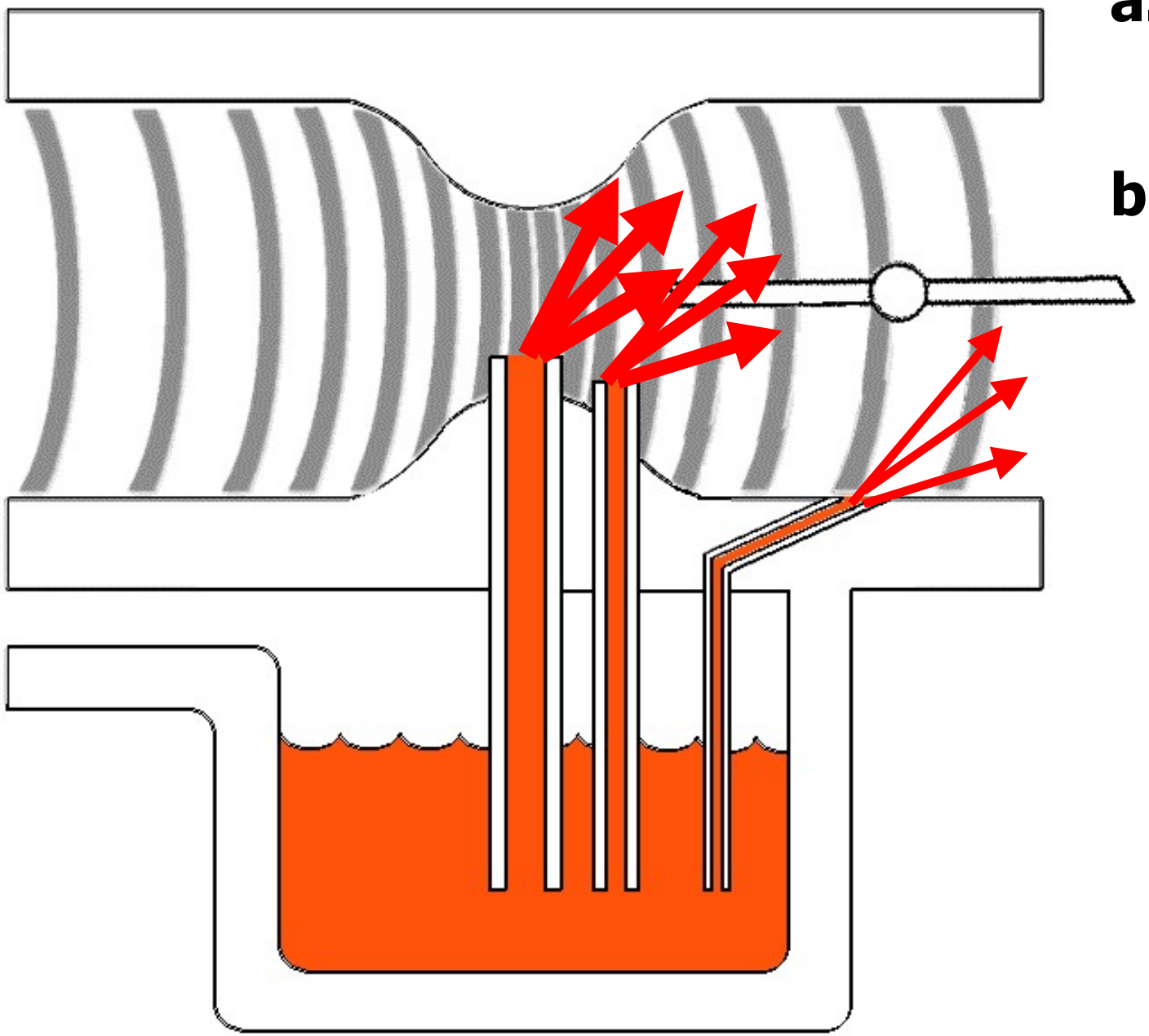
(3 basic circuits, cont.)

2. Midrange
   a. Throttle is opened
   b. Increase in airflow increases press. difference at midrange tube, its fuel flow is added to that of idle tube (idle tube is still flowing)
   c. Most ridden circuit



(3 basic circuits, cont.)

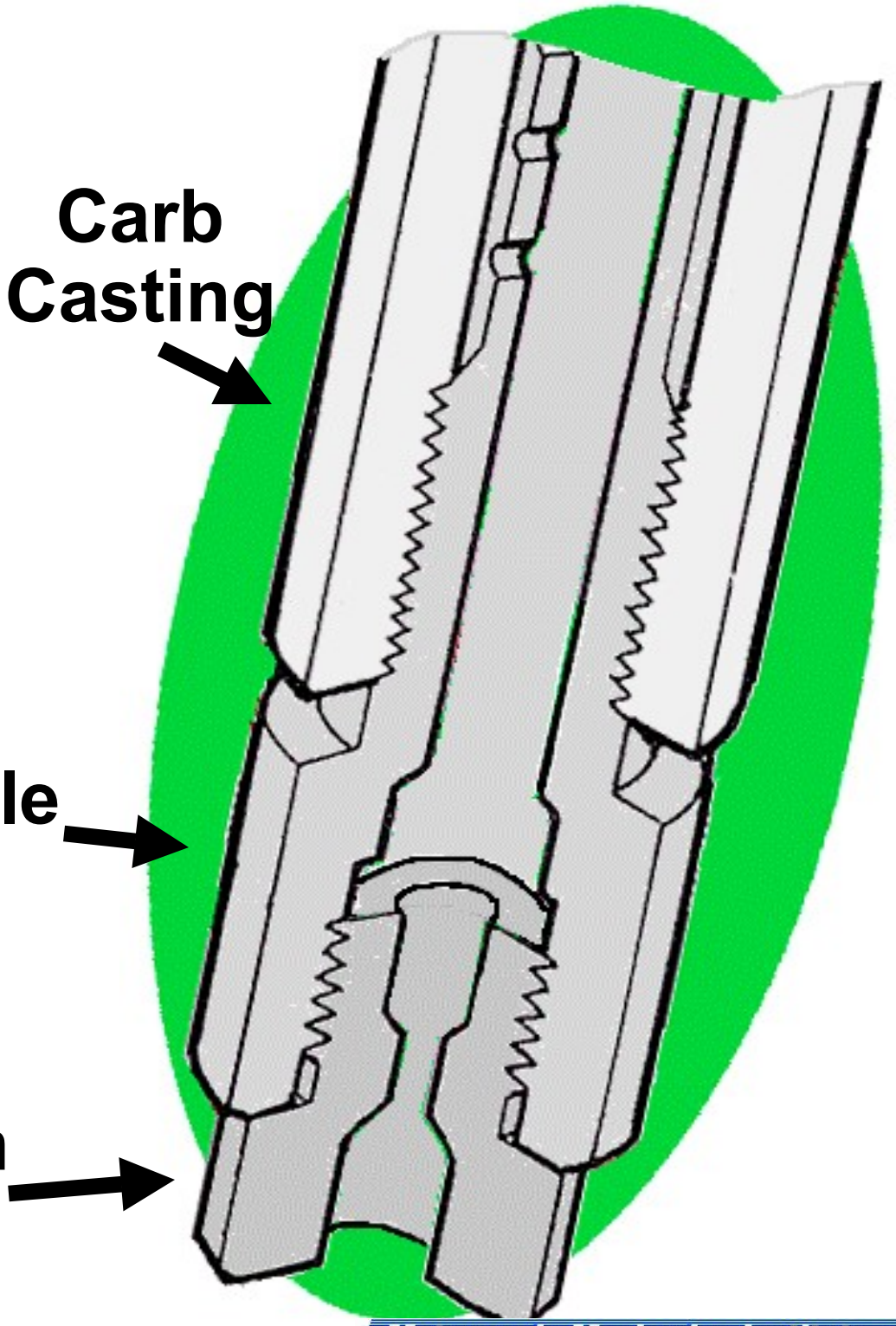
3. Main
   a. Throttle is opened all the way
   b. Increase in airflow increases press. difference at main tube, its fuel flow is added to that of the idle and midrange tubes (idle and midrange tubes are still flowing)



(The Basic Carb, cont.)

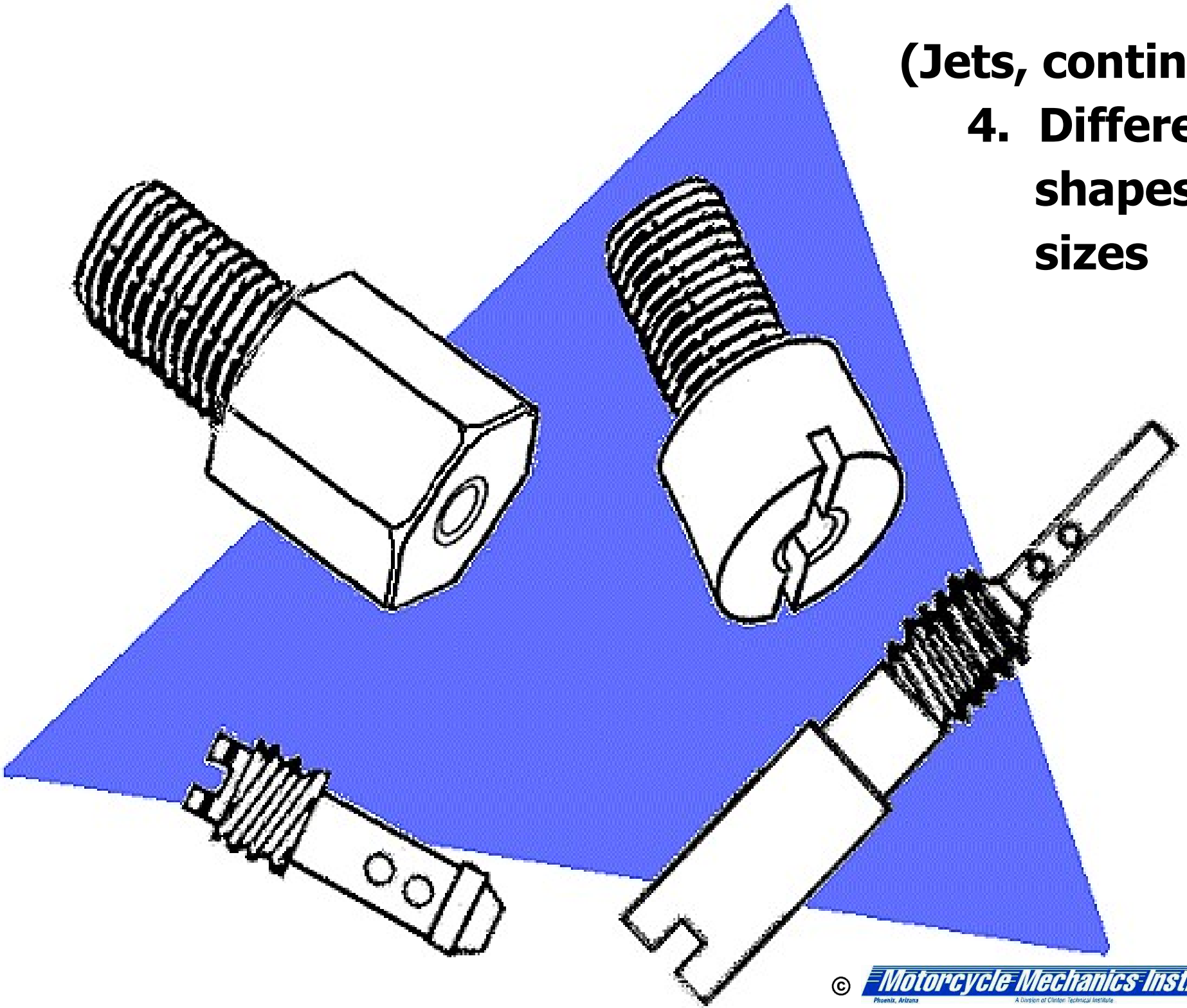
B. Jets

1. **A jet is an added-on restriction used to "size" the fuel tube**
2. **Usually each fuel tube has a jet**
3. **Not always replaceable**



(Jets, continued)

4. Different shapes and sizes

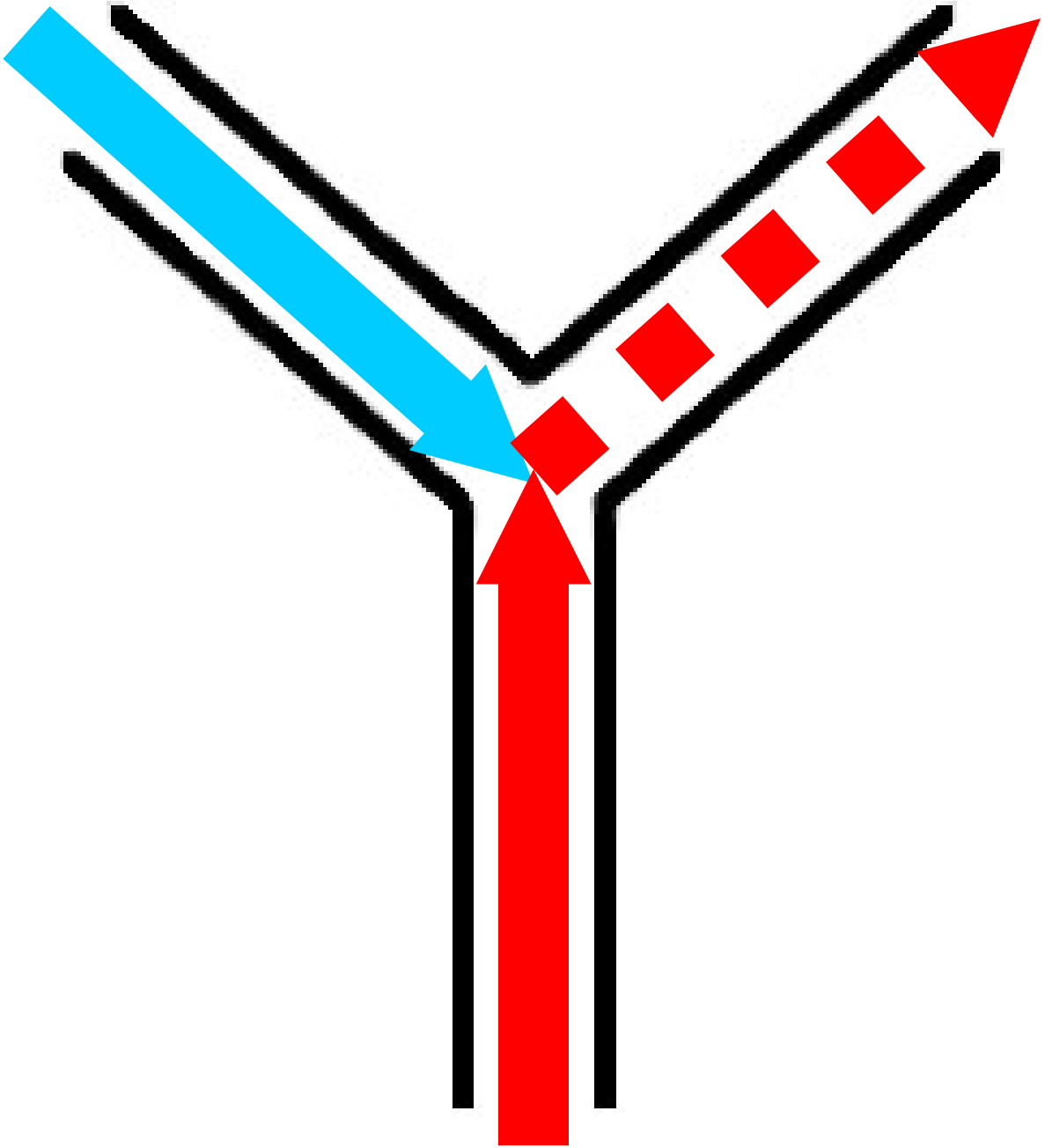


(The Basic Carb, cont.)

C. Air bleeds

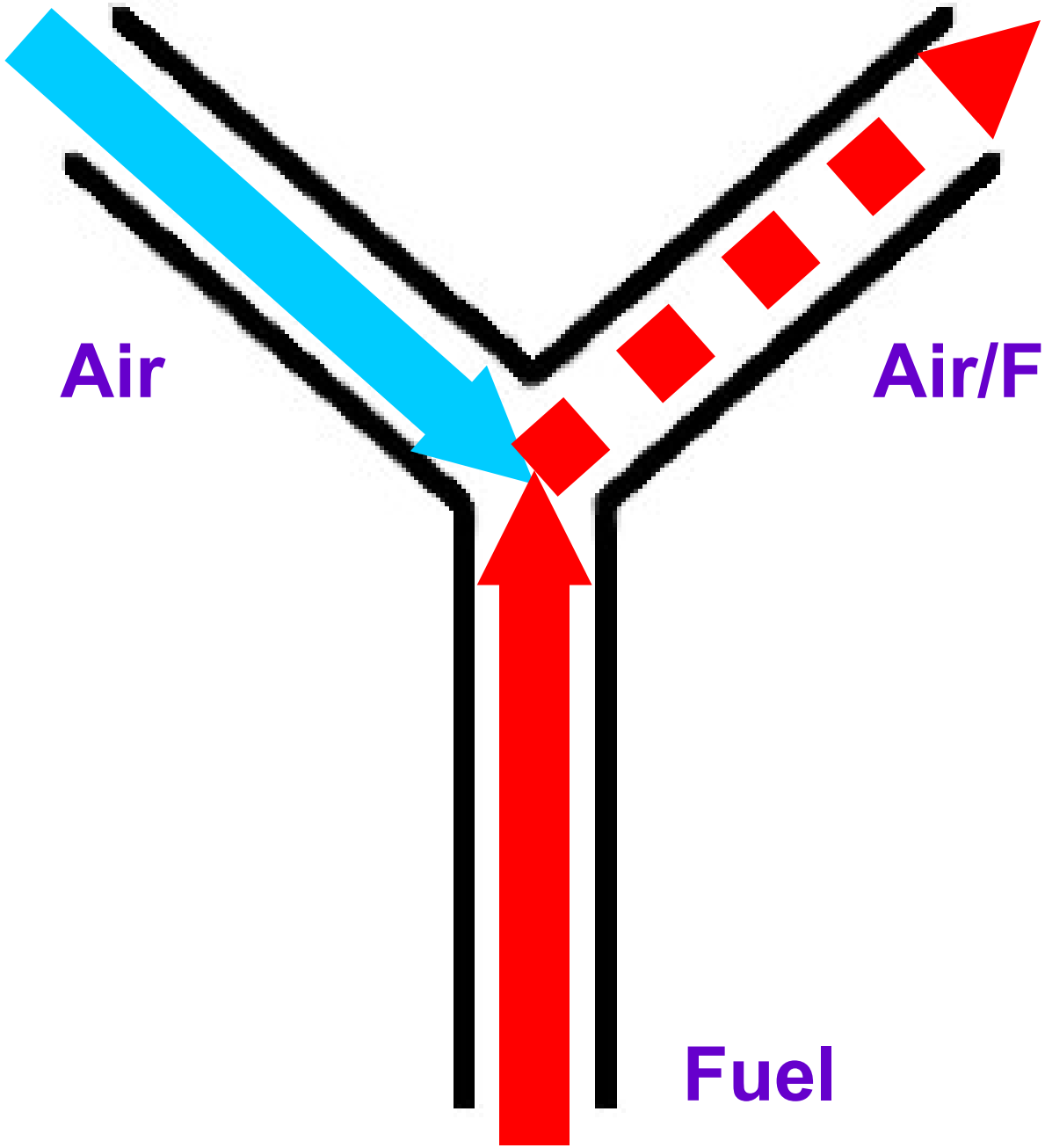
1. The "Y" principle

   a. Every atomizing circuit has three openings



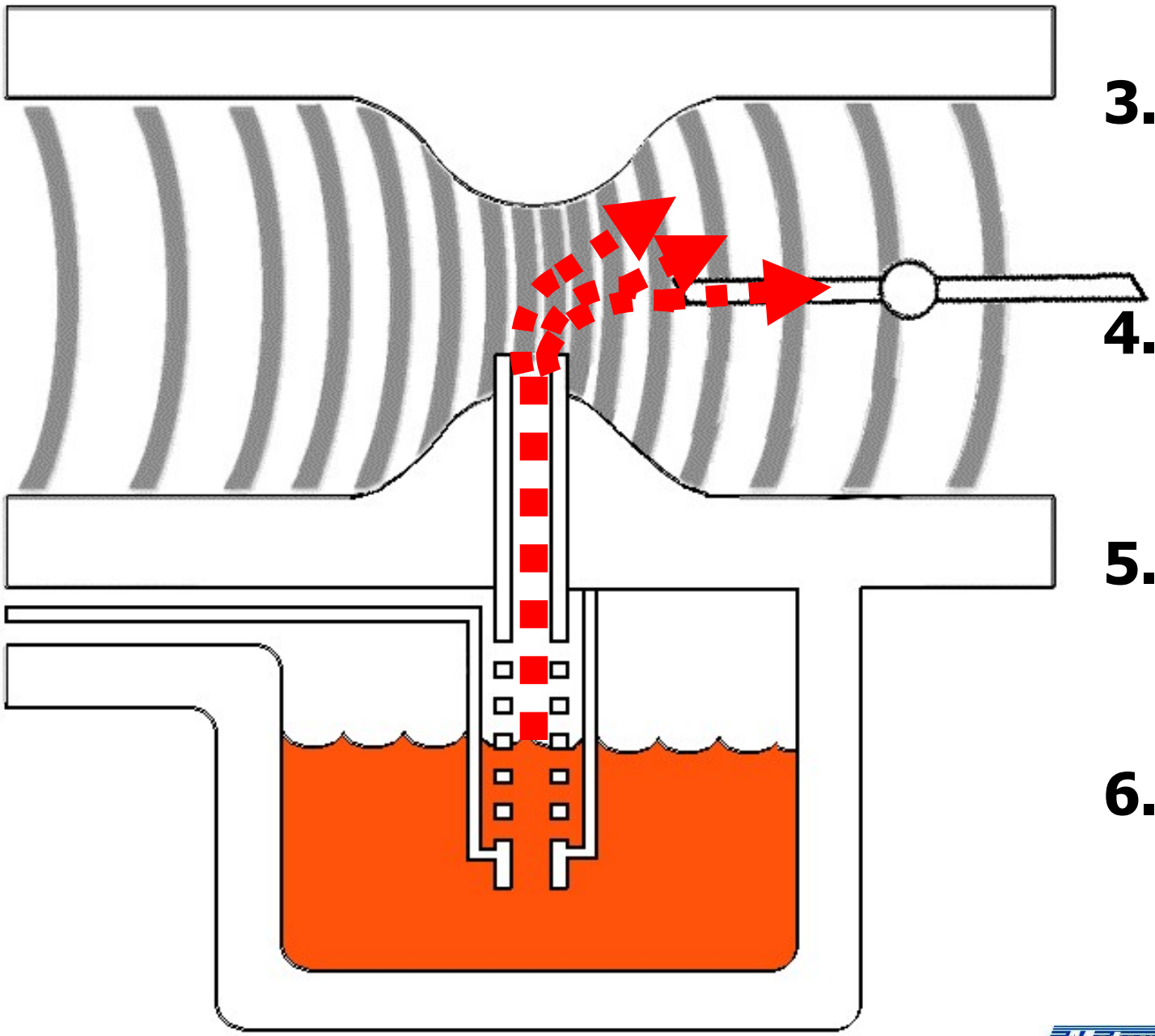
(The Basic Carb, cont.)

C. Air bleeds
   1. The "Y" principle
      a. Every atomizing circuit has three openings
      b. Ensures adequate atomization of the fuel

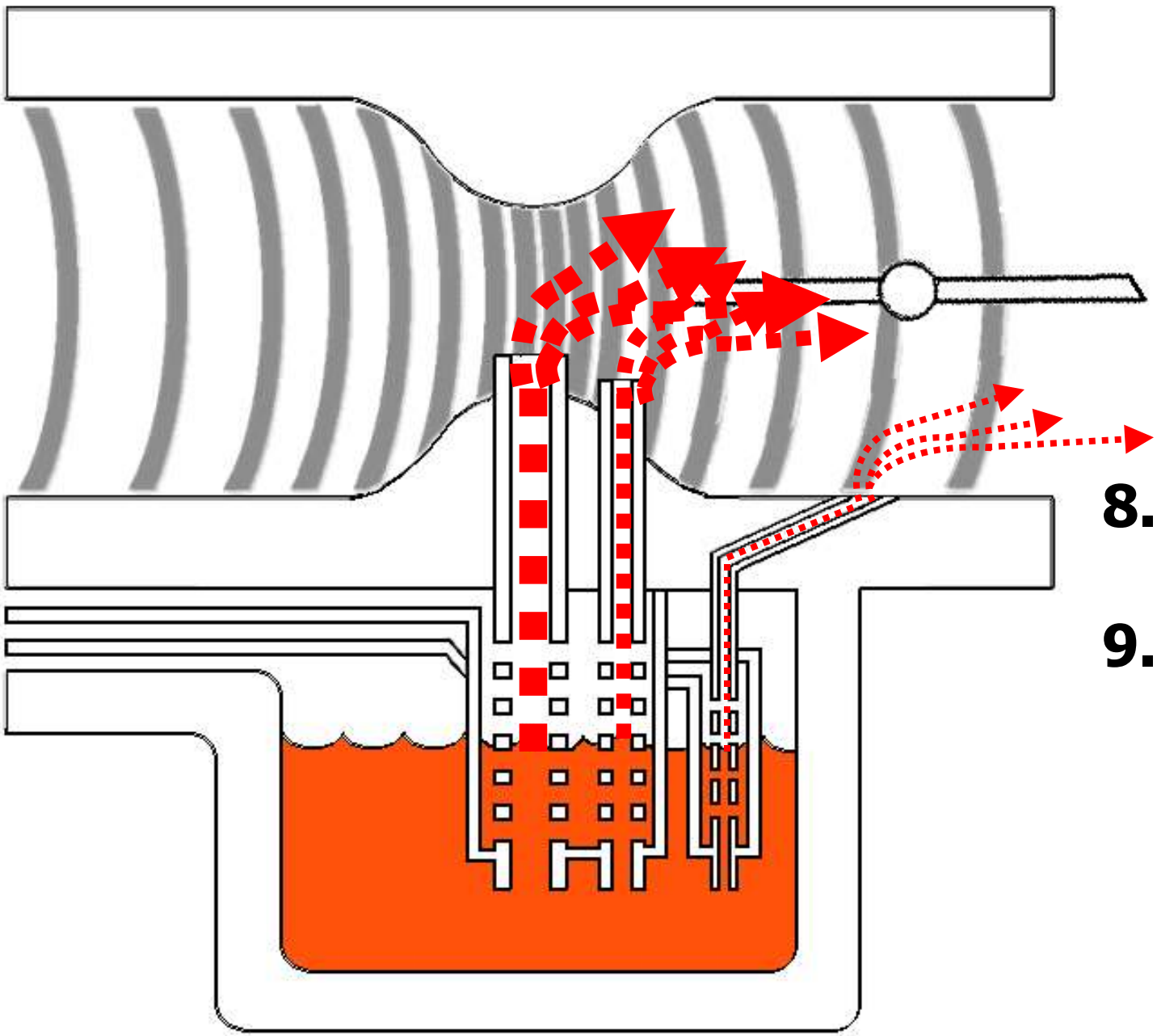


(Air bleeds, cont.)

2. Holes drilled in fuel tube
3. Tube is surrounded by an air cavity
4. Air cavity is vented to atmosphere
5. Atmospheric press. aerates rising fuel
6. Makes discharge a fine mist

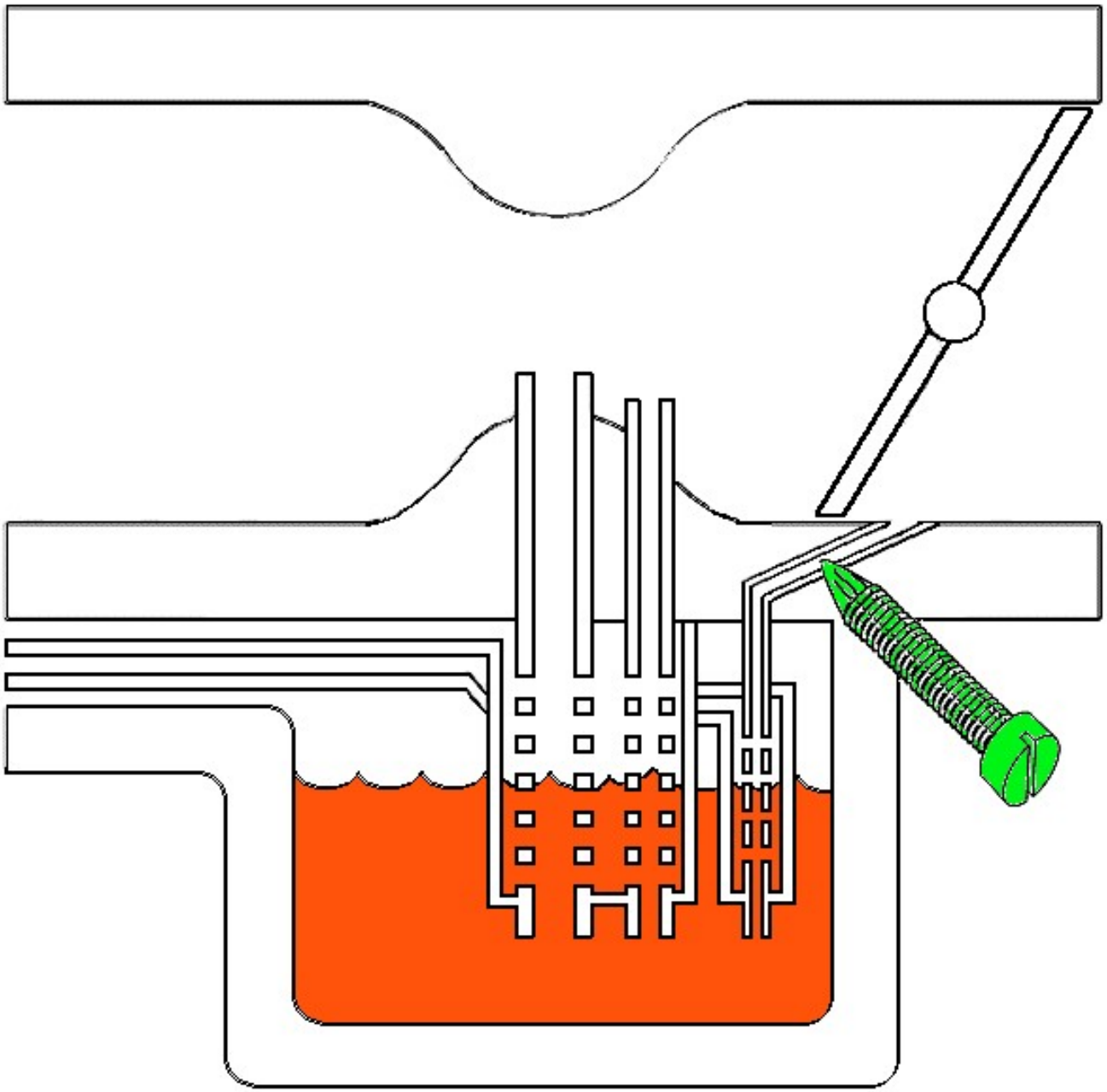


(Air bleeds, cont.)



7. This mist is more easily vaporized by the engine, resulting in greater combustion efficiency
8. All tubes have air bleeds
9. Midrange circuit often shares one with either idle or main

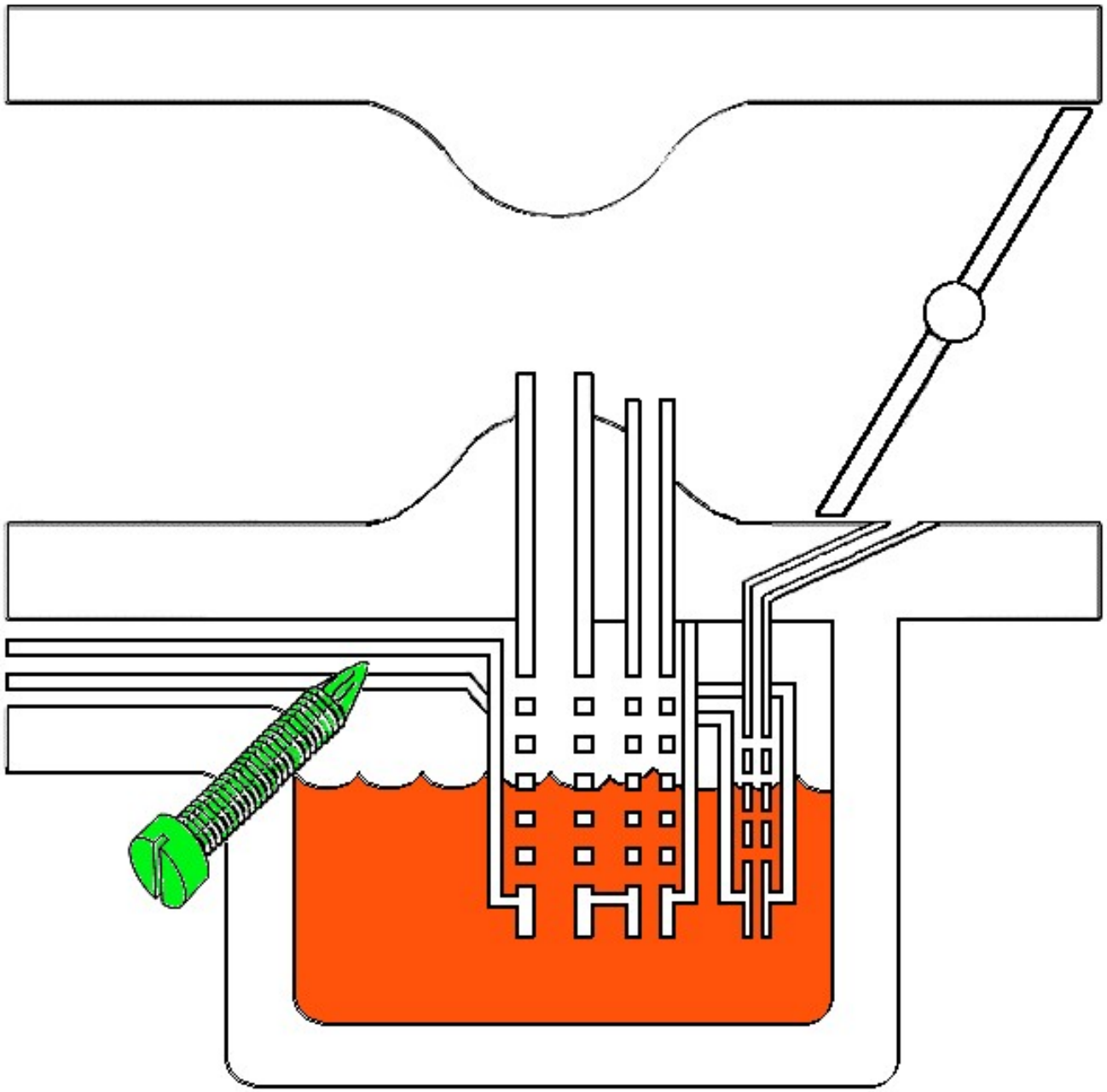
(The Basic Carb, cont.)



- D. Idle mixture screw
  1. Combustion least efficient at idle
  2. Two kinds
     - a. Fuel screw
       1) Threads into the idle fuel passage
       2) Meters both air and fuel together
       3) In = lean, out = rich

(Two kinds, cont.)

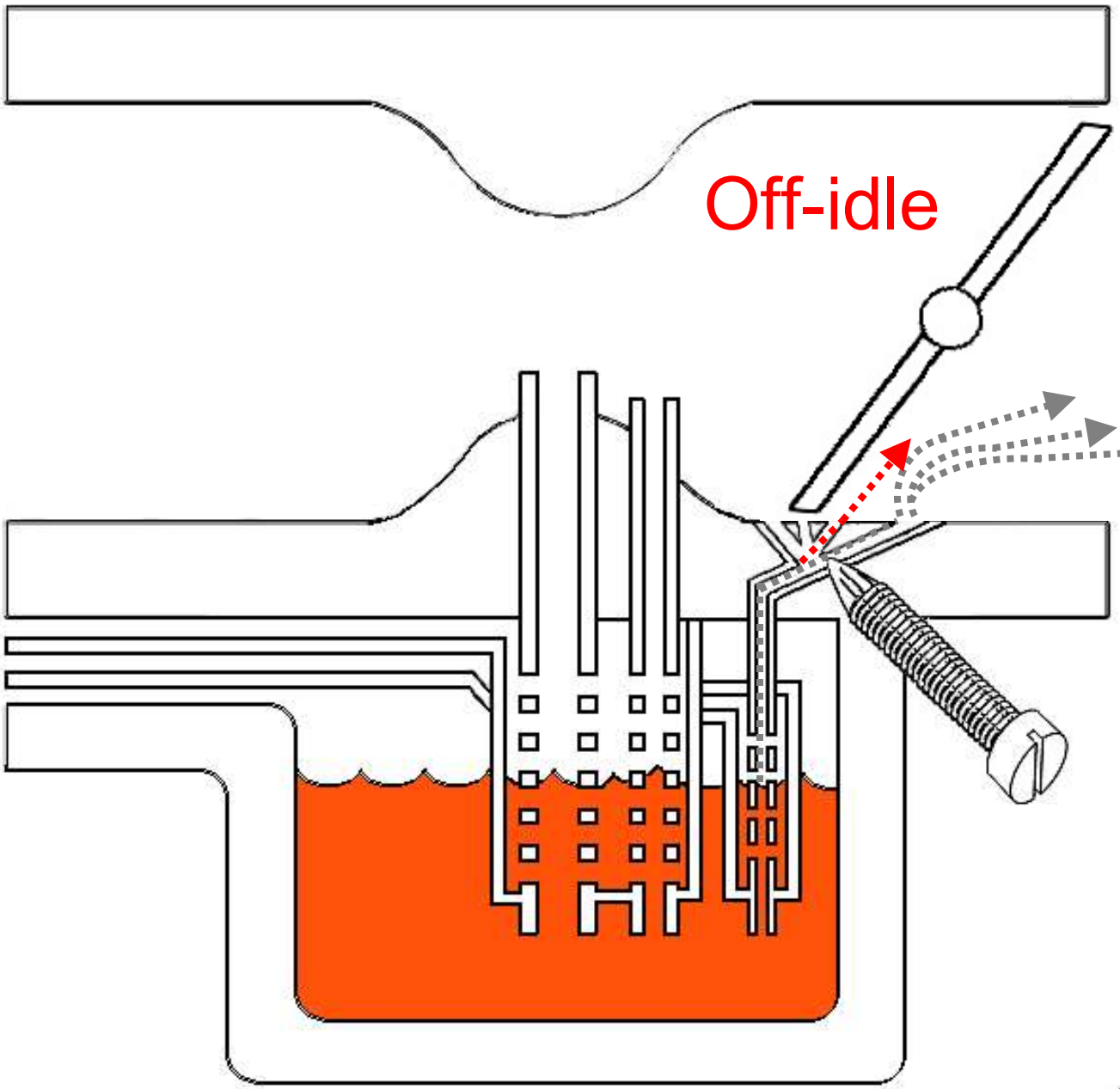
- b. Air screw
  1) Threads into idle air passage
  2) Meters air only
  3) In = rich, out = lean



(The Basic Carb, cont.)

E. Transfer ports

1. "Sprinklers"
2. Staged
3. Usually 2-4
4. Fed by idle circuit
5. Also called bypass ports
6. Even though a circuit, not counted as a separate circuit (it's part of idle circuit)
7. Controlled by the throttle



(The Basic Carb, cont.)

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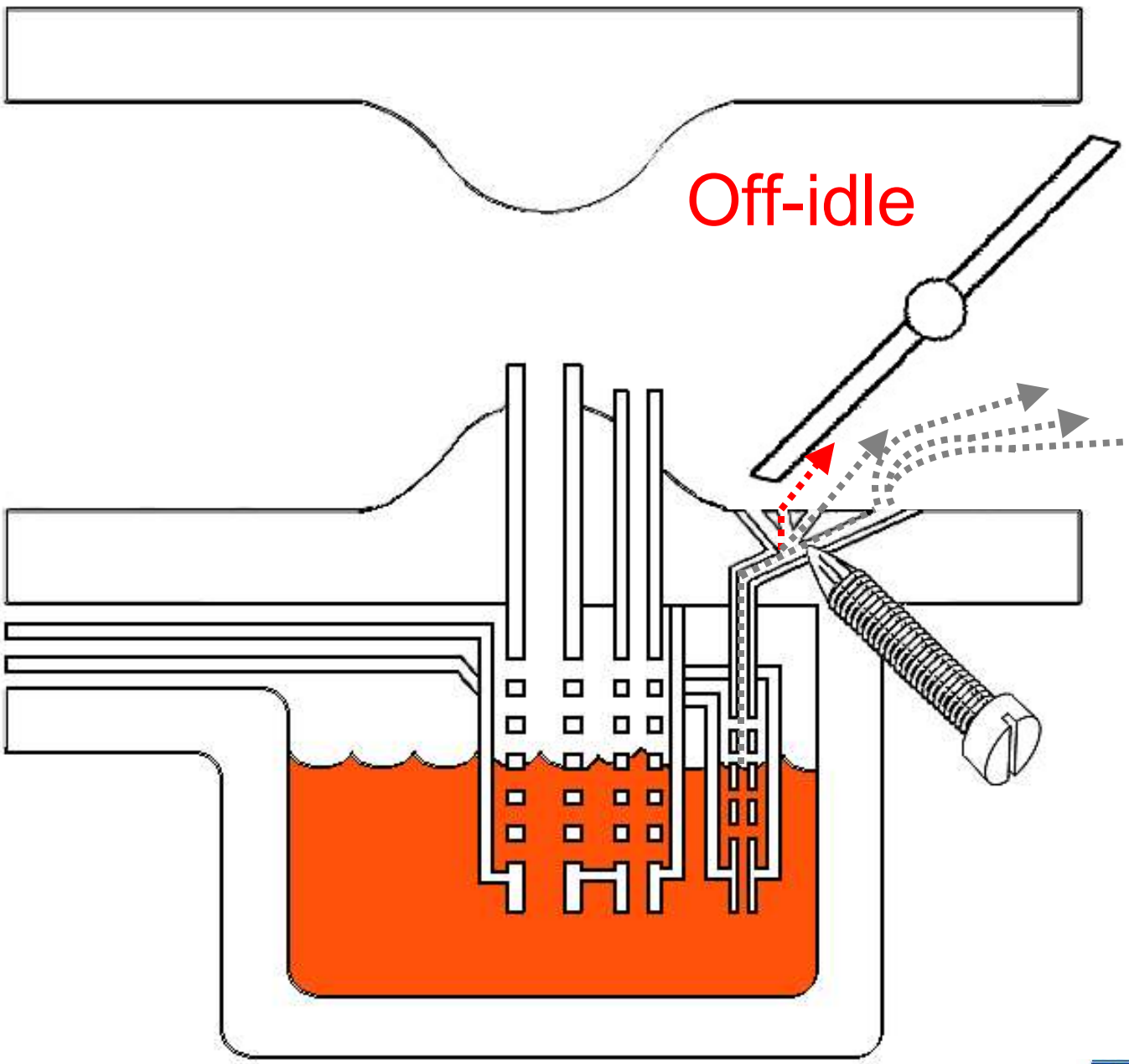

(The Basic Carb, cont.)

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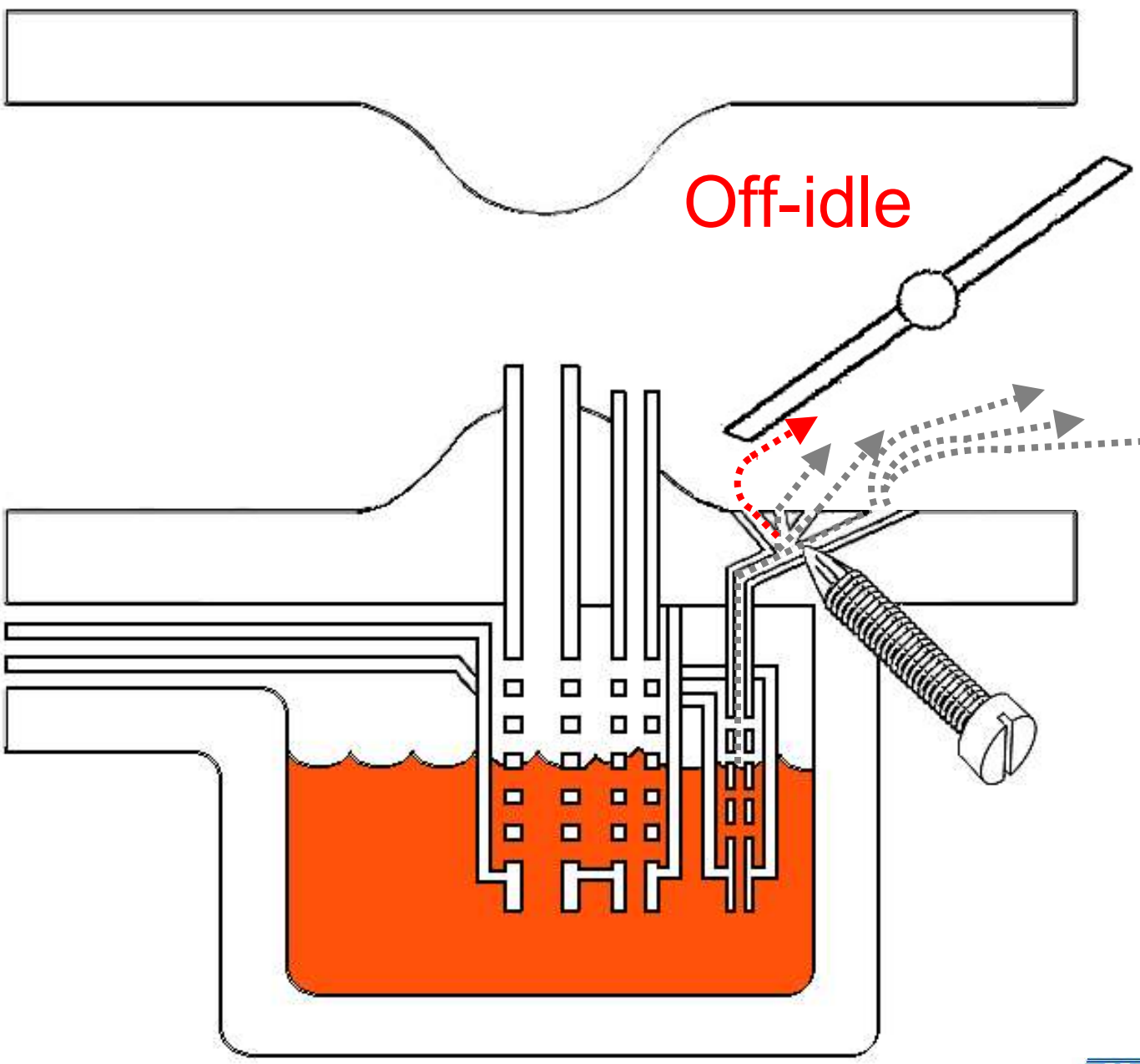
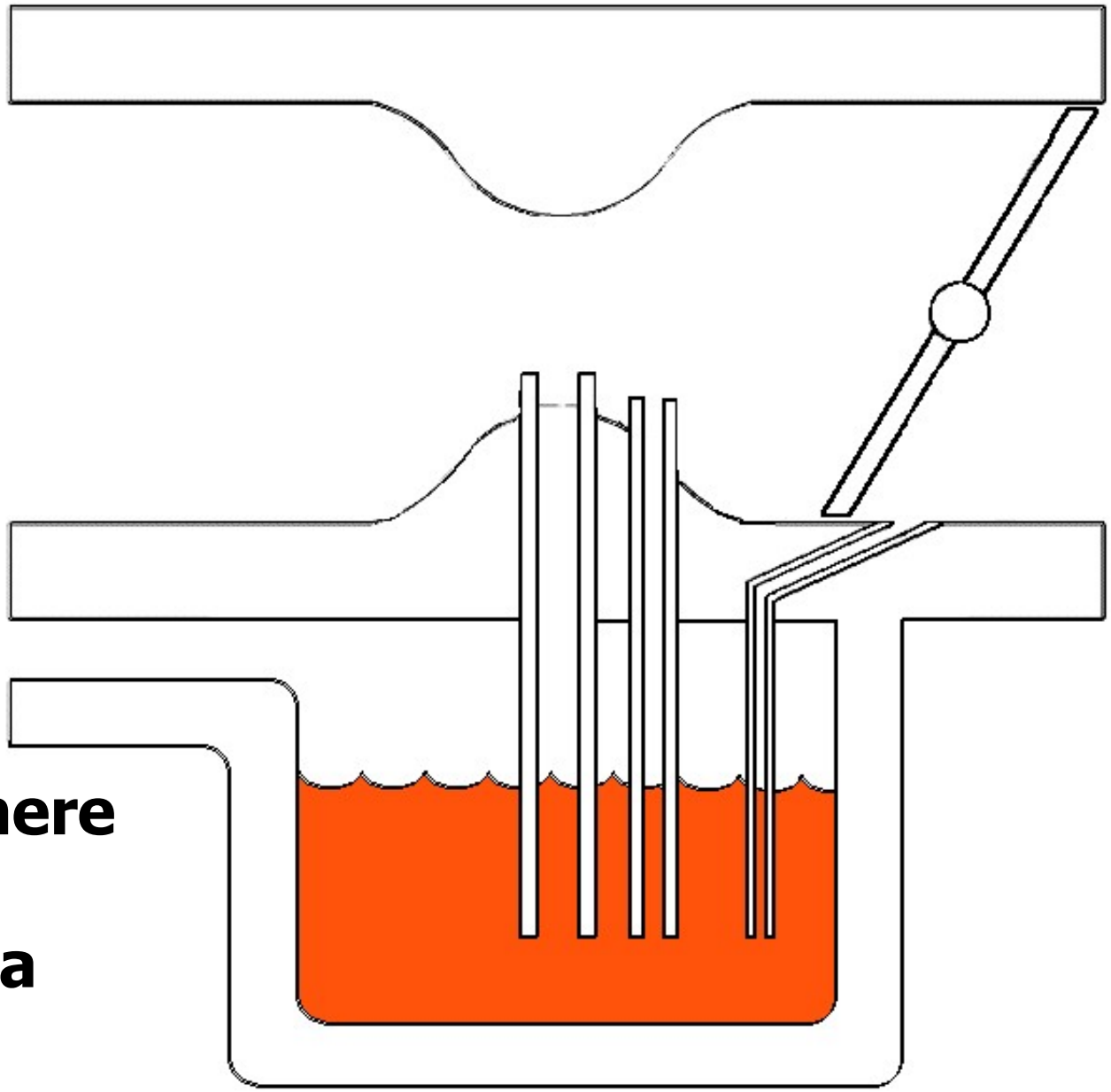
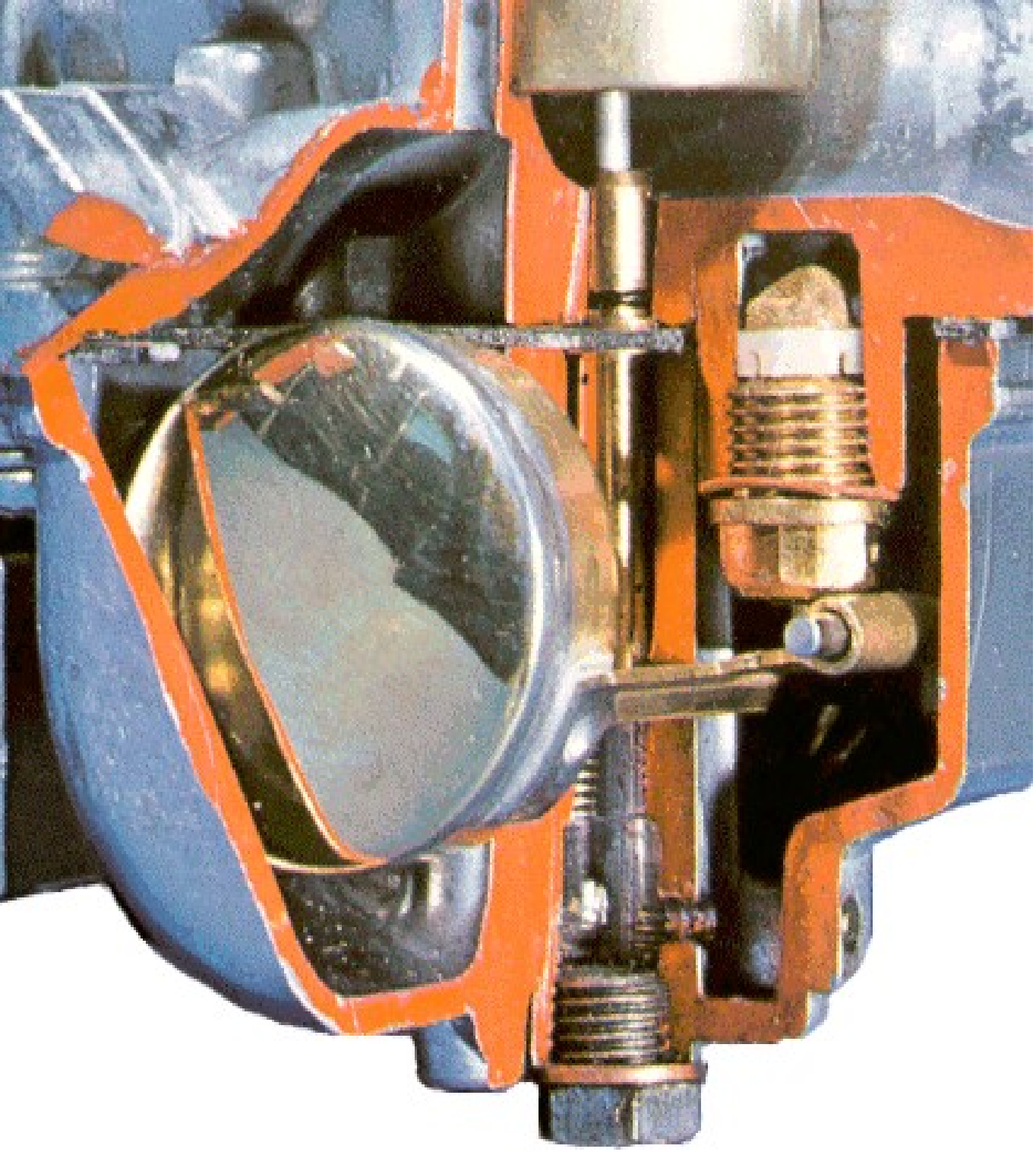


(The Basic Carb, cont.)

F. Float system
   1. Fuel level affects all circuits
   2. More = richer, less = leaner
   3. Vented
      a. *Boyle's Law*
      b. Atmosphere
      c. Airbox
      d. California (Evap)



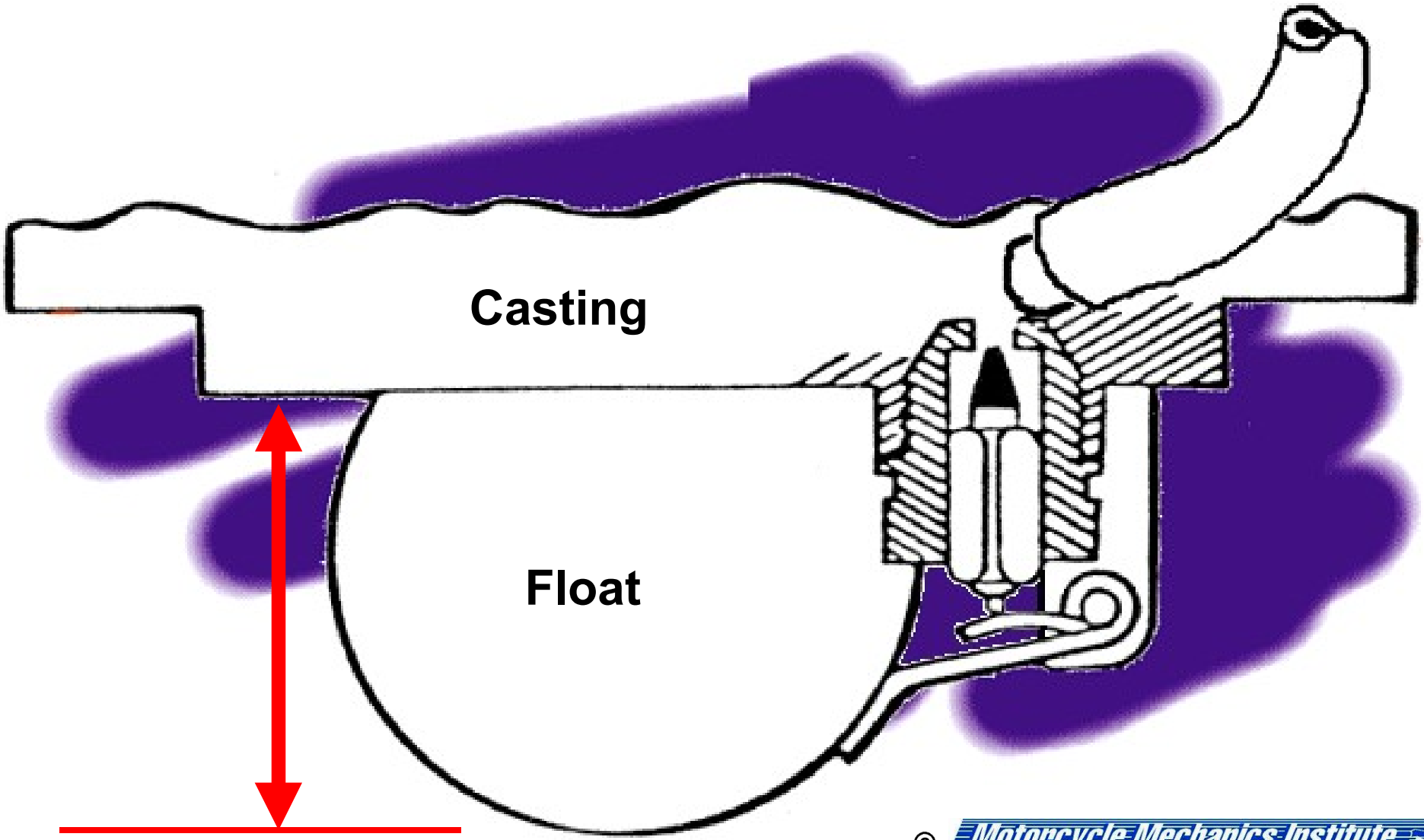


(Float system, cont.)

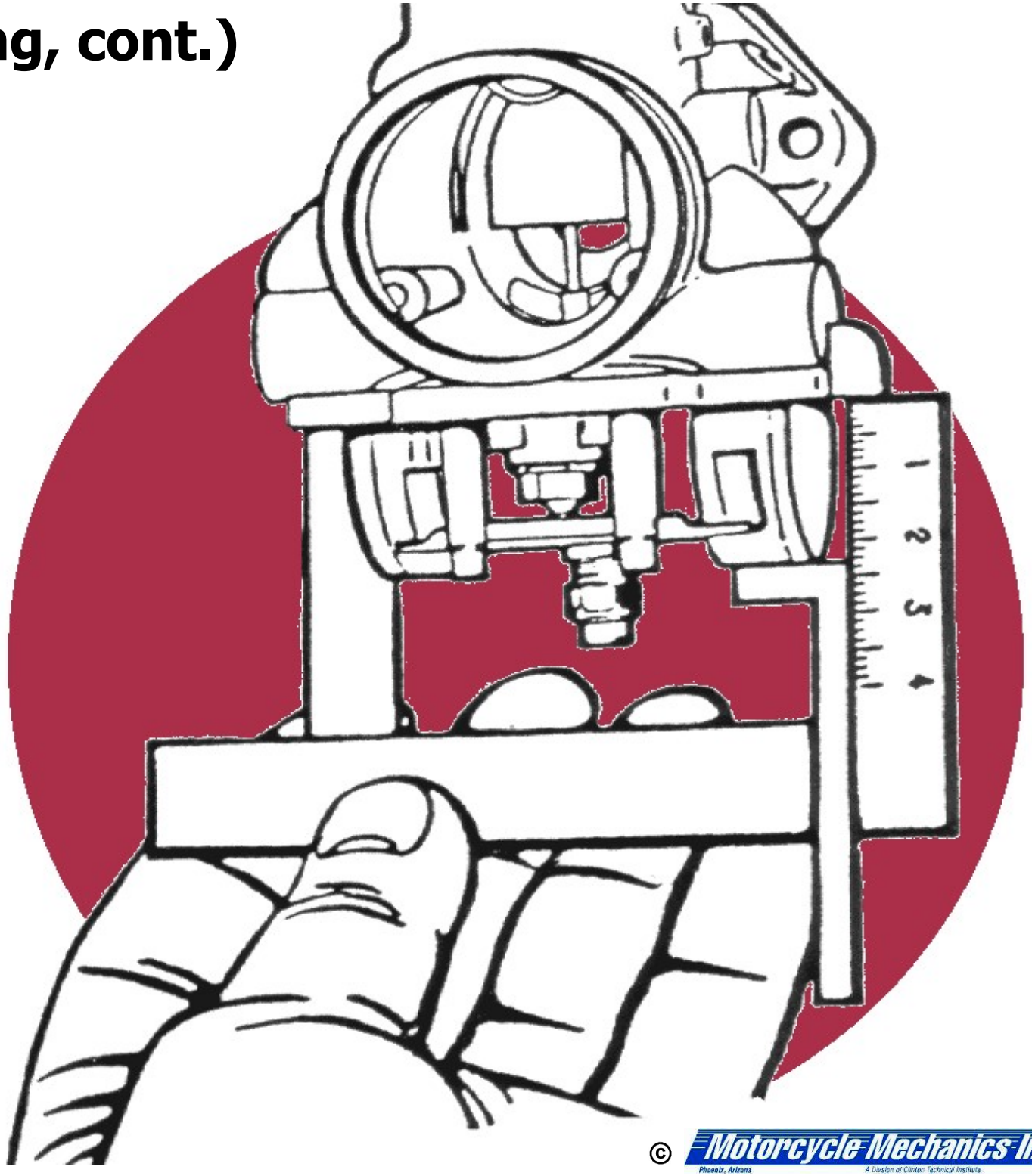
4. Float valve assembly
   a. Needle
      1) Often Viton-tipped
      2) May be spring-loaded
   b. Seat
      1) Threaded or cast in place
      2) May have removable screen

(Float system, continued)

5. Measuring
    a. Distance from bottom of float to casting
        1) High fuel level = small number = richness
        2) Low fuel level = large number = leanness



(Measuring, cont.)

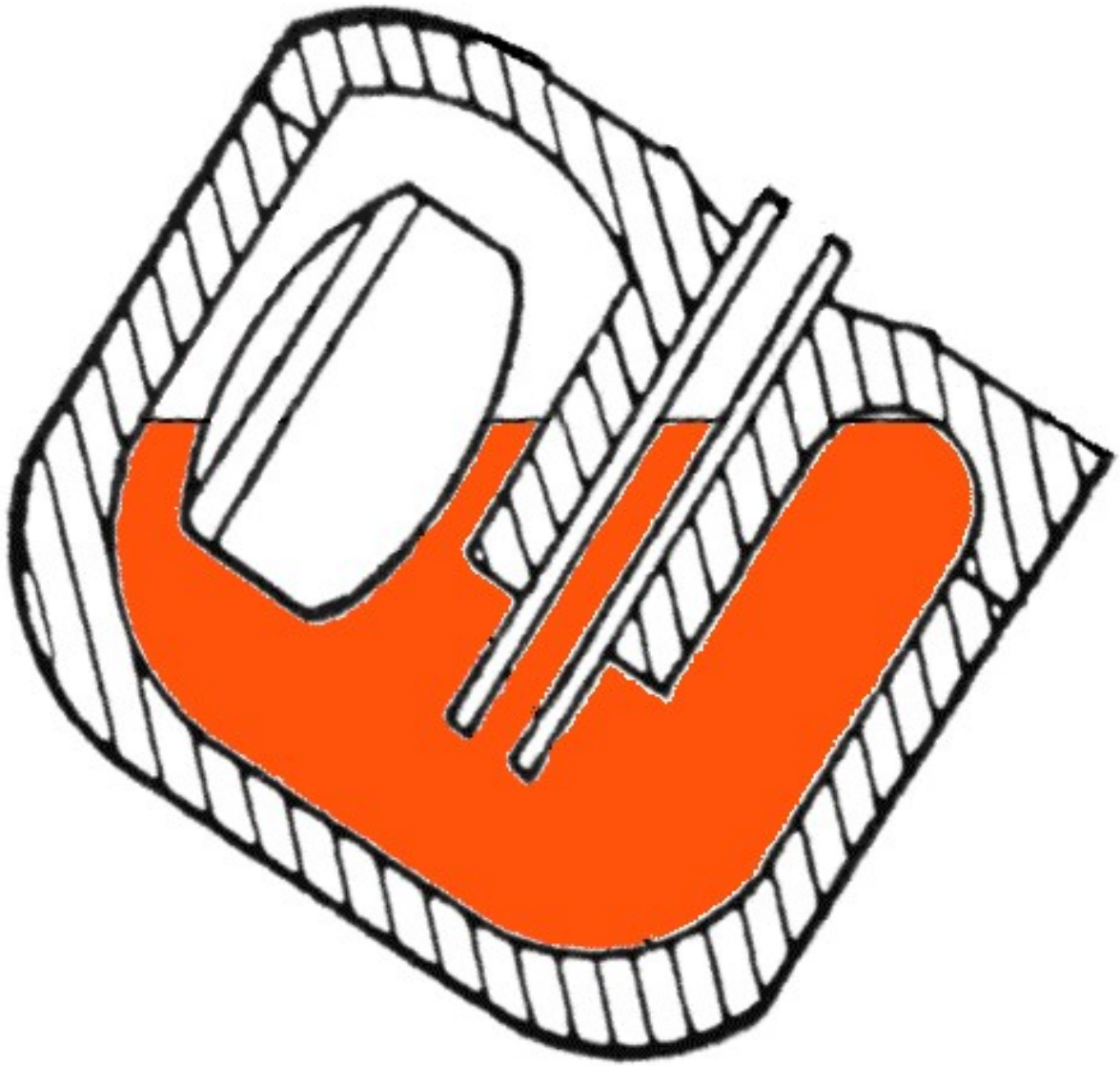


(Float system, continued)

6. Configurations
   a. Concentric
      1) Main tube in center
      2) Stable fuel level

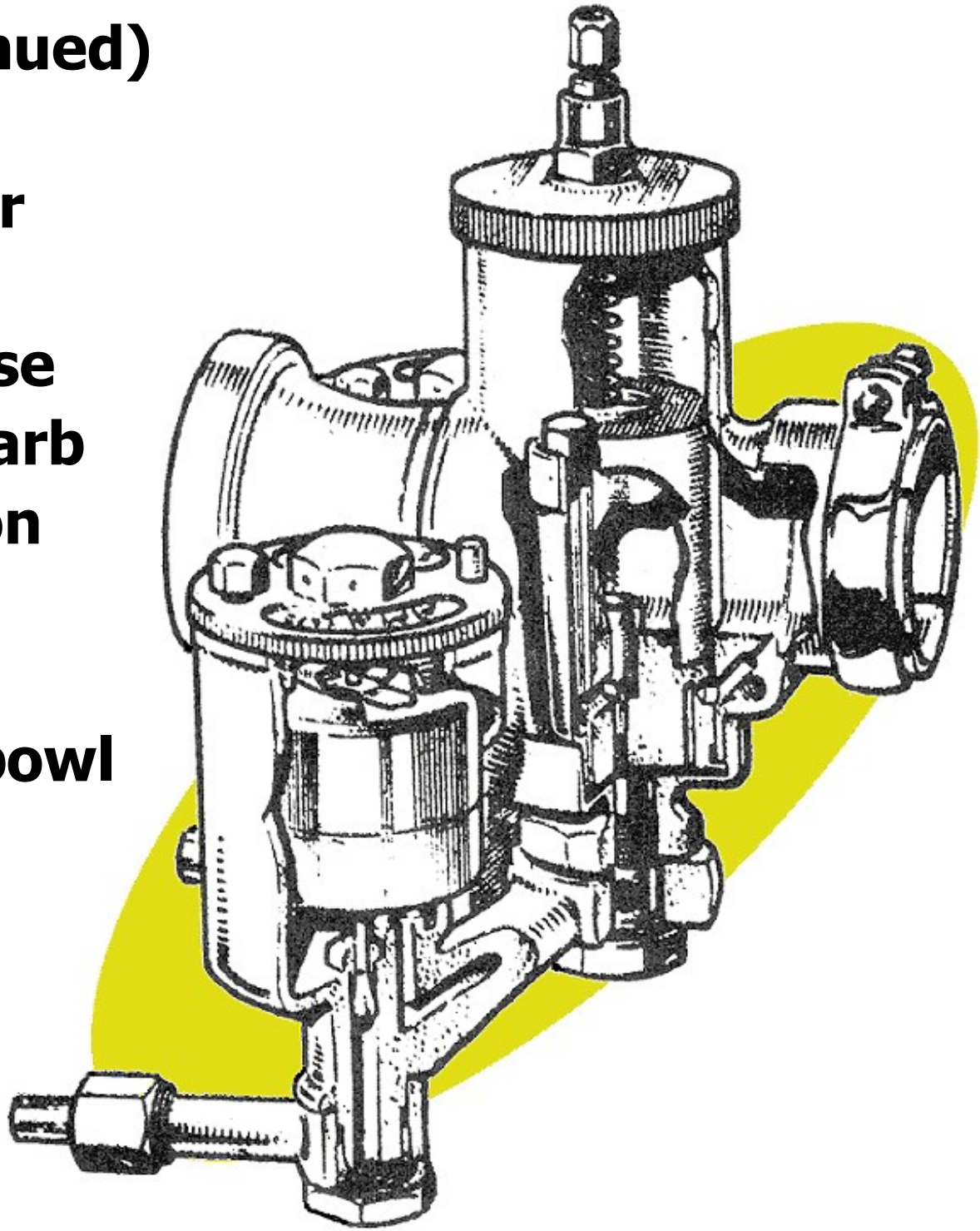
(Configurations, cont.)

b. Eccentric
    1) Main tube to one side
    2) Different fuel level, right and left turns



(Configurations, continued)

c. Remote
   1) Float chamber connected by casting or hose
   2) May be one carb with bolted-on float bowl
   3) Or two carbs sharing one bowl

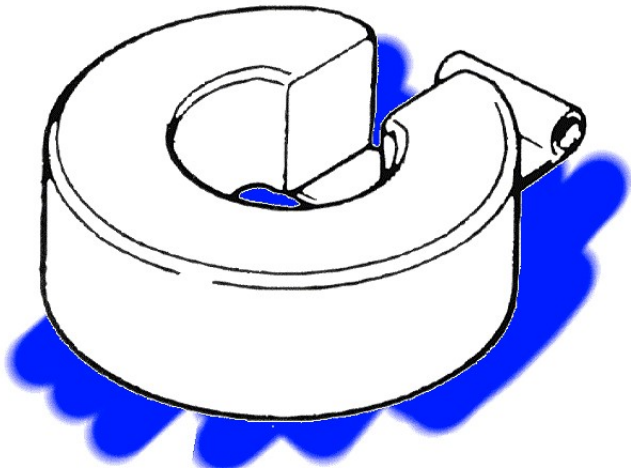


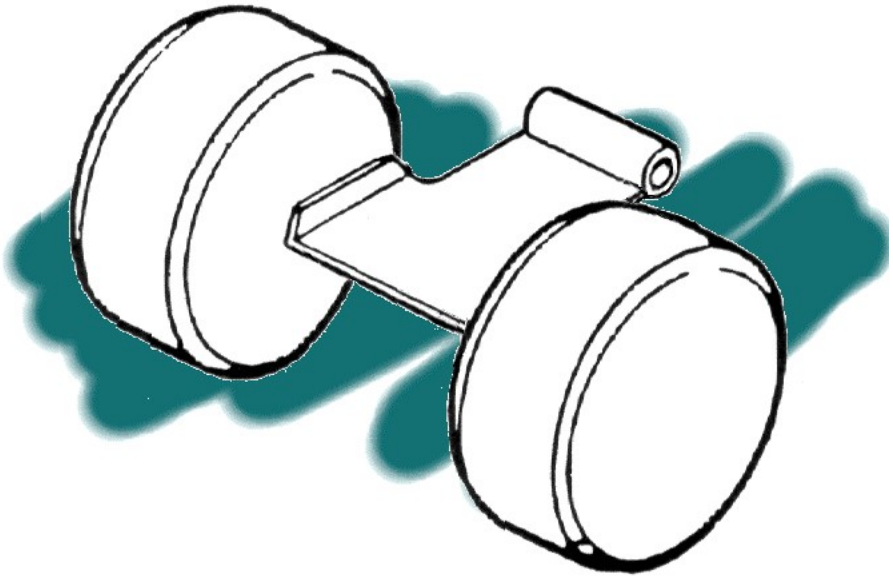
(Float system, continued)

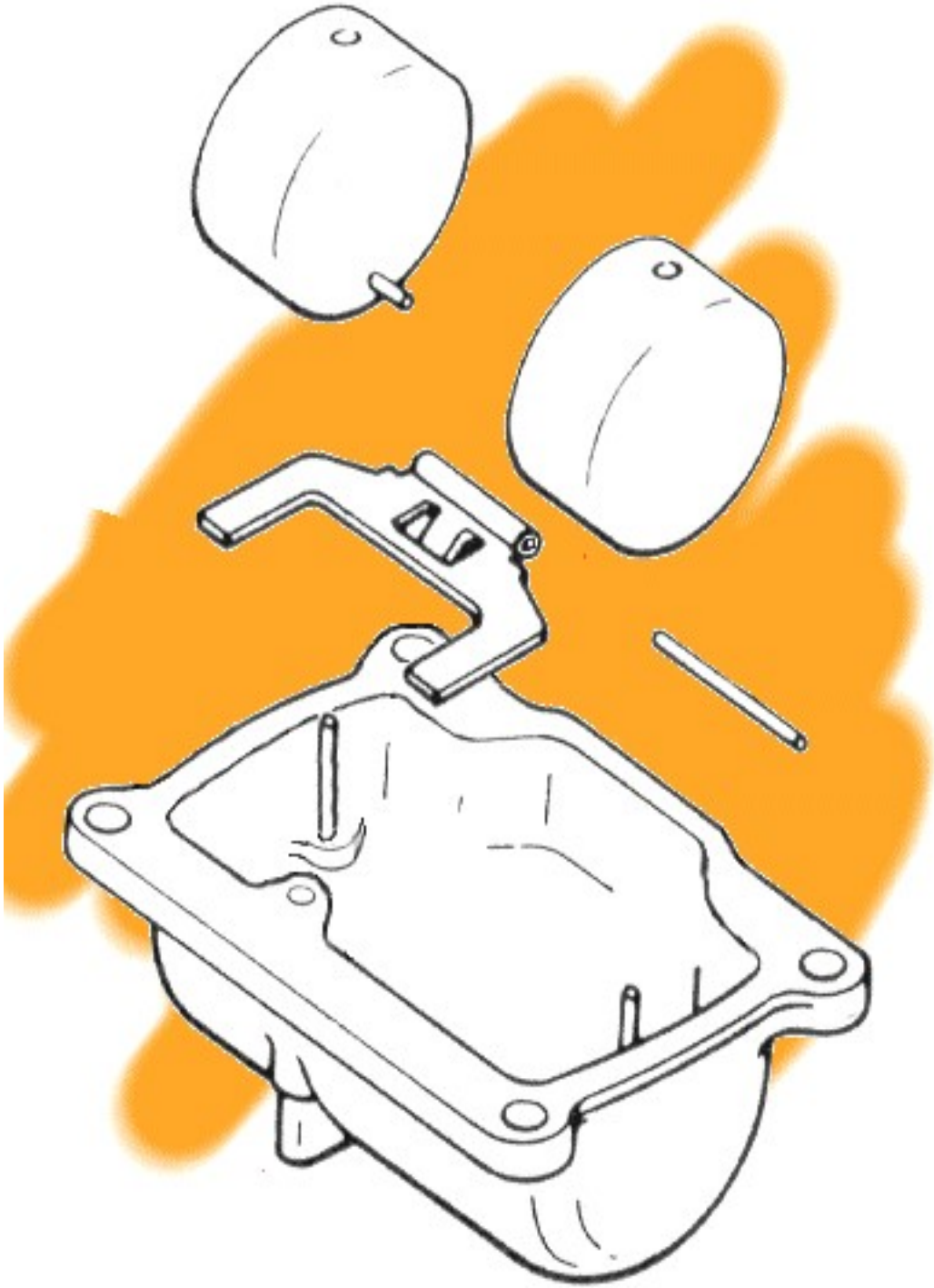
7. Float materials
    a. Hollow brass
        1) Soldered together
        2) Delicate
    b. Solid plastic
        1) Long-lasting
        2) Affected by exotic fuels
    c. Hollow plastic
        1) Common
        2) May be non-adjustable

(Float system, continued)

8. **Float types**
   a. **Single**
   b. **Twin**
   c. **Independent**







(The Basic Carburetor, cont.)

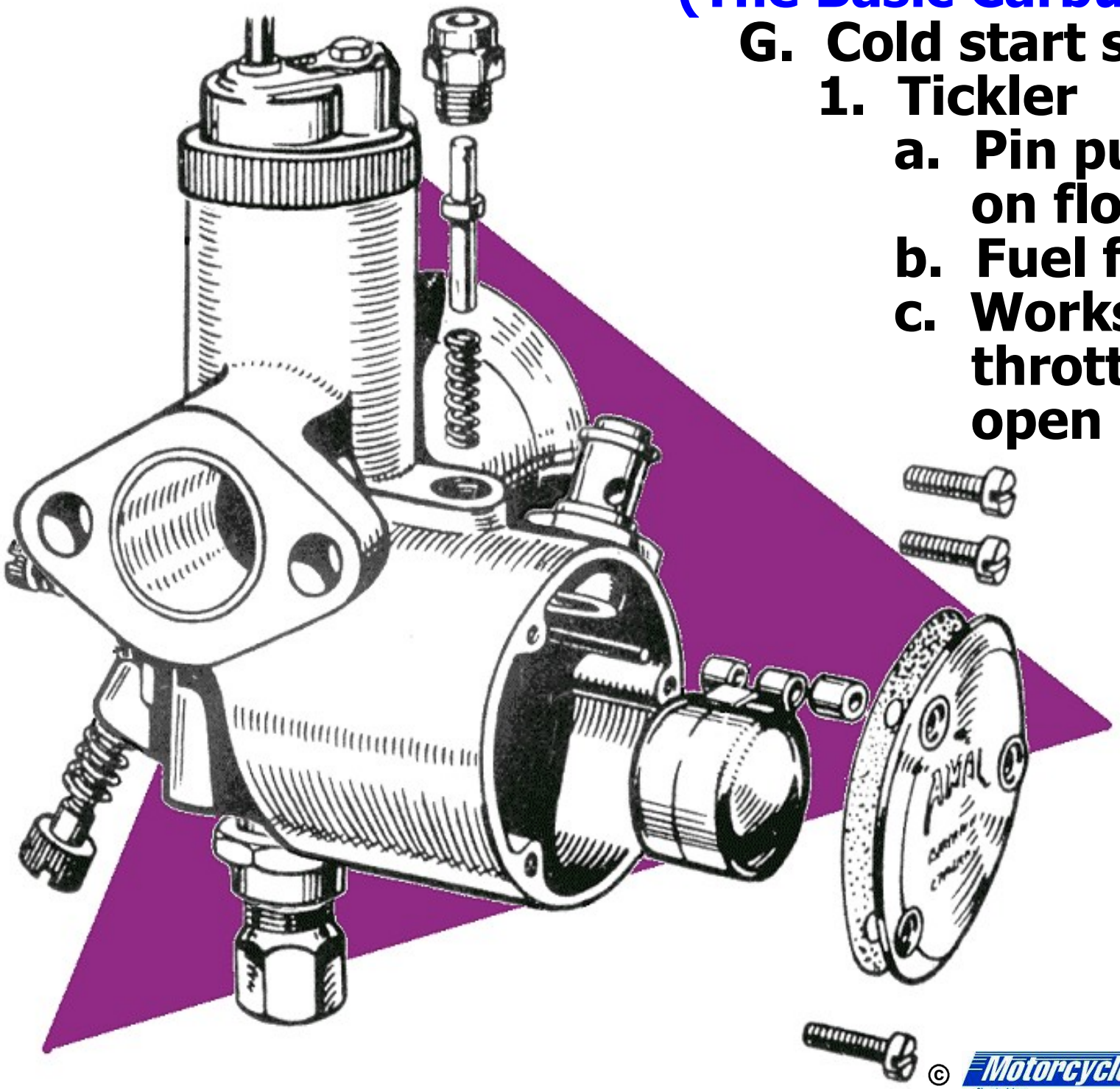
G. Cold start systems

1. Tickler

a. Pin pushes down on float

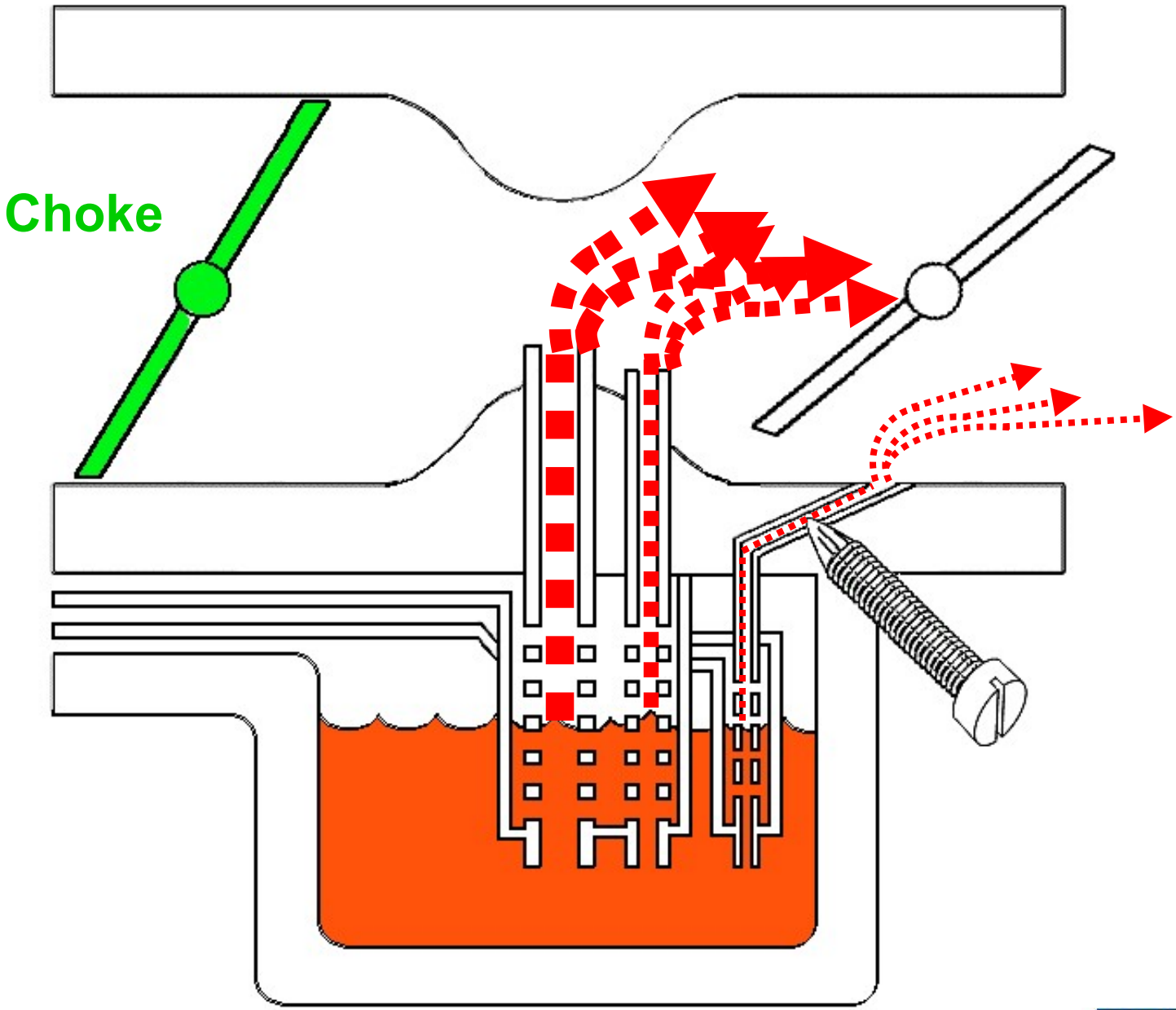
b. Fuel floods venturi

c. Works best with throttle slightly open



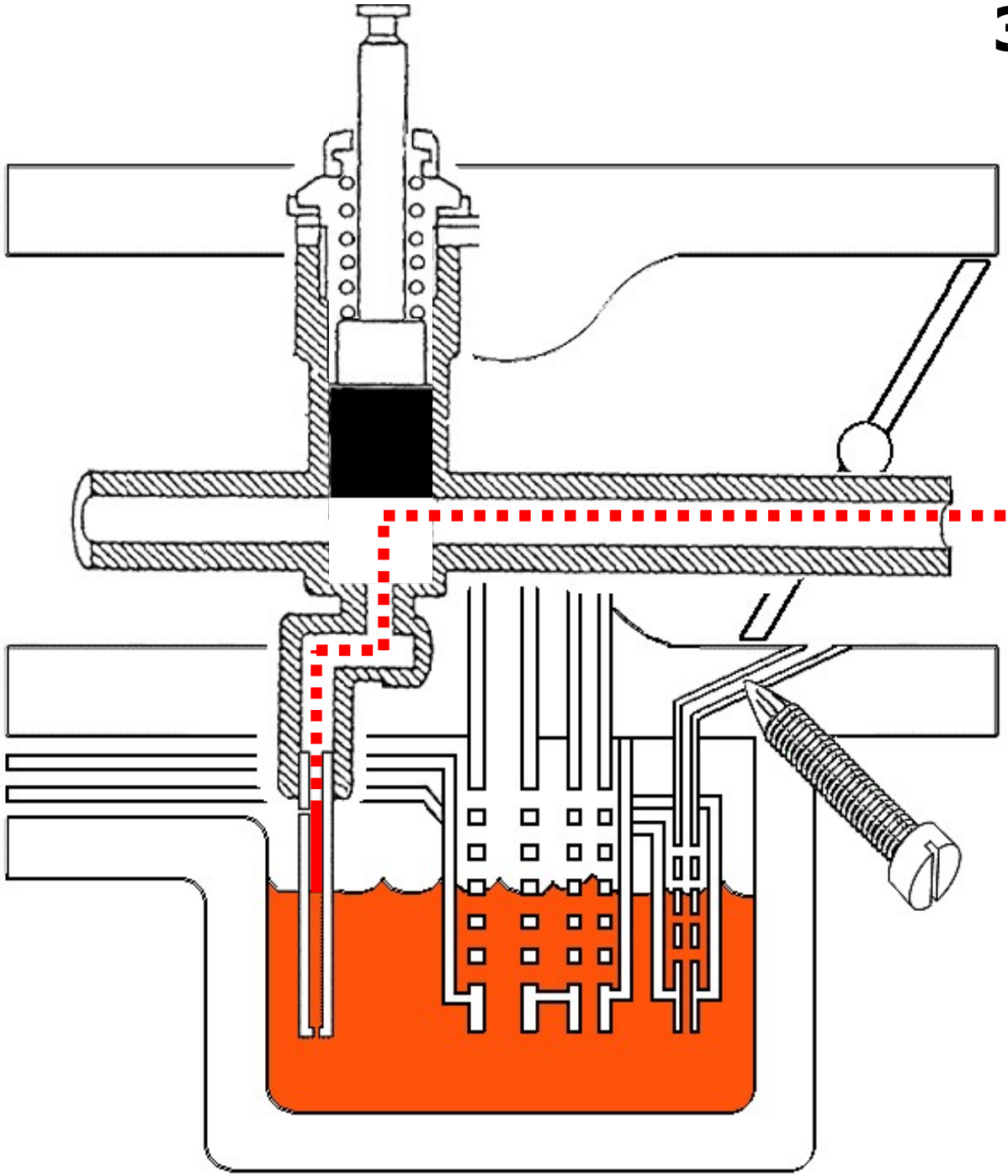
(Cold start systems, cont.)

2. Choke
   a. Plate closes to create a huge press. difference at fuel tubes
   b. All tubes discharge
   c. Works best with throttle slightly open



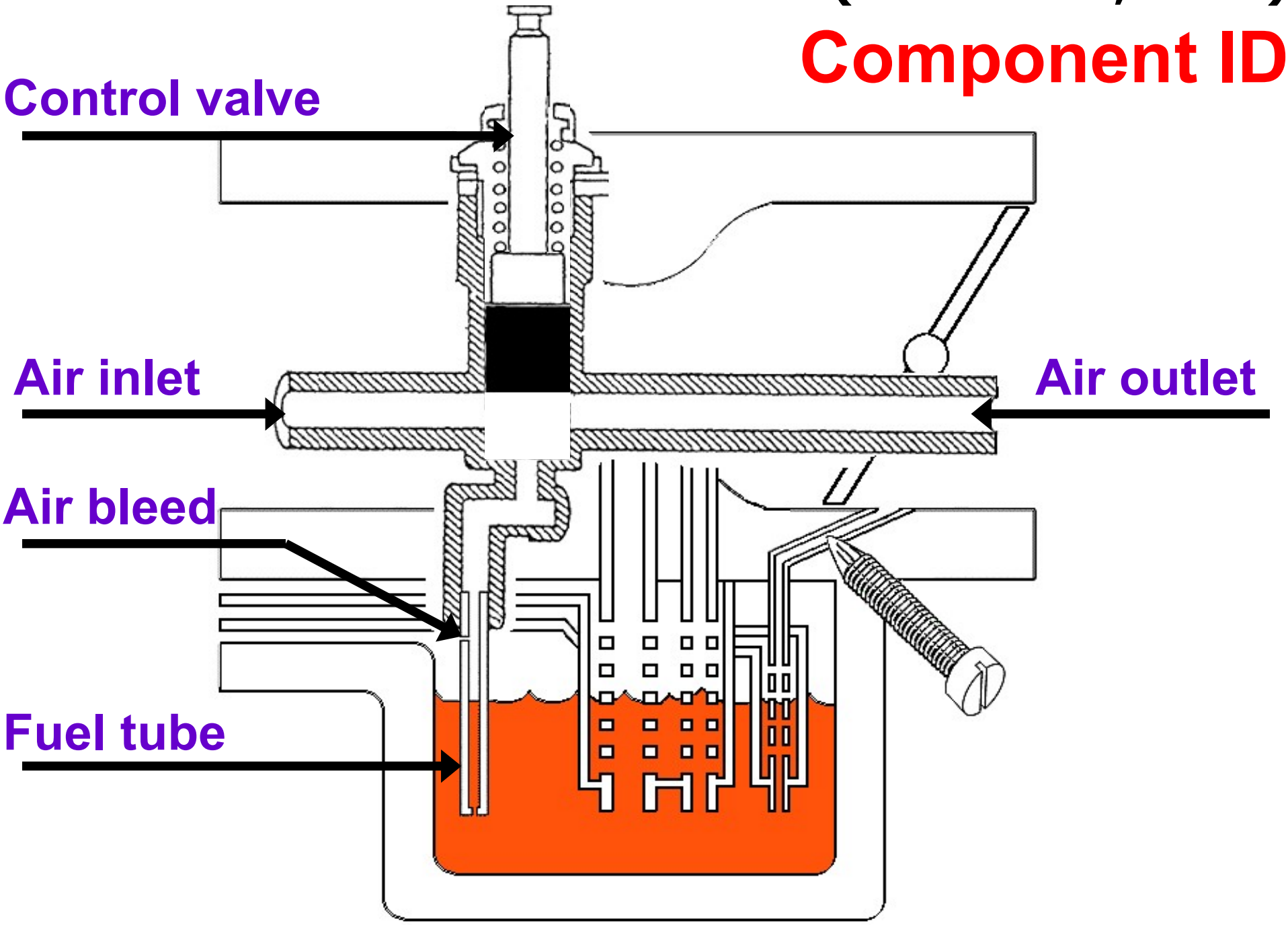
(Cold start systems, cont.)

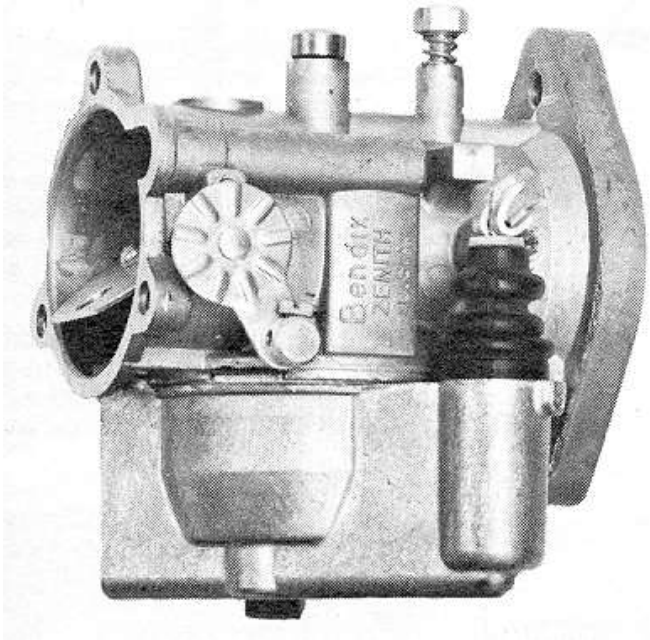
3. Enrichener
   a. Mini carburetor jetted just for starting
   b. Joined at bowl
   c. Works best with throttle closed

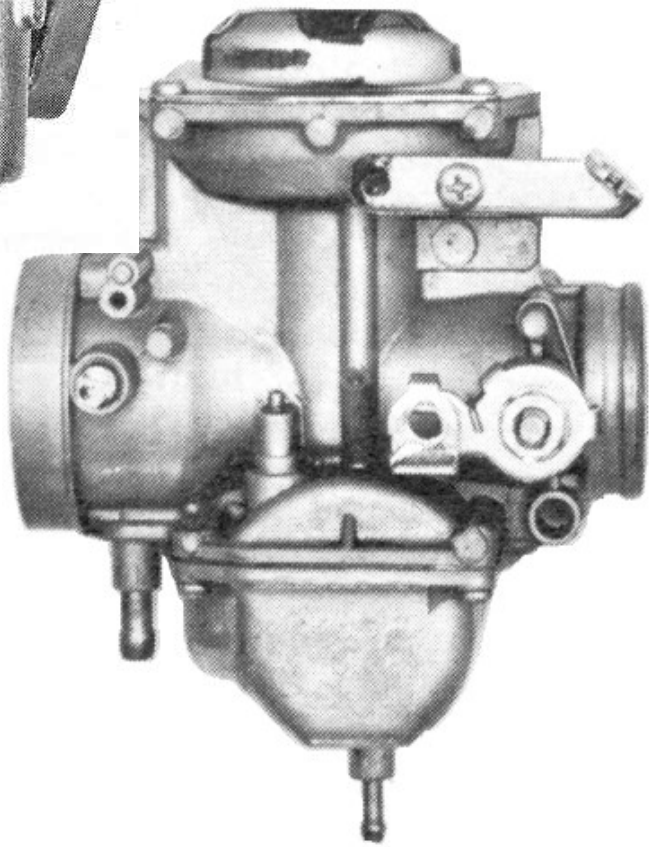


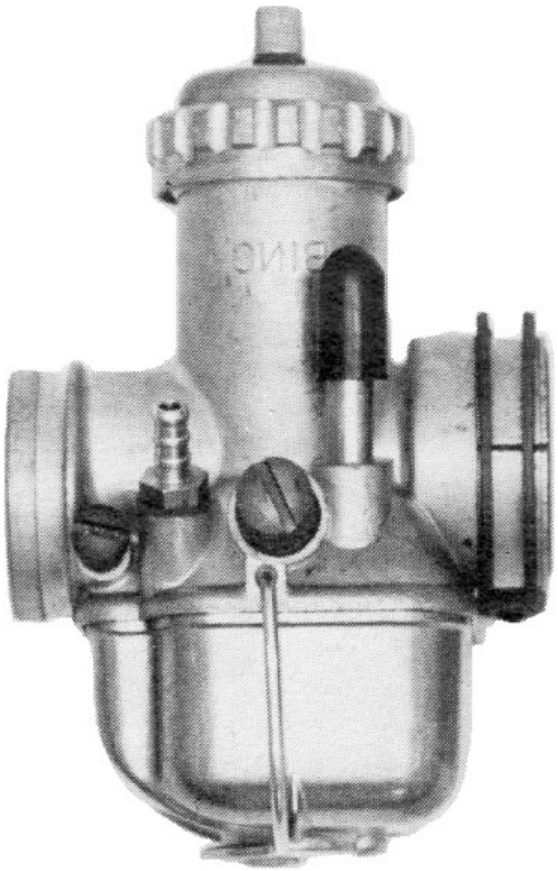
(Enrichener, cont.)

Component ID









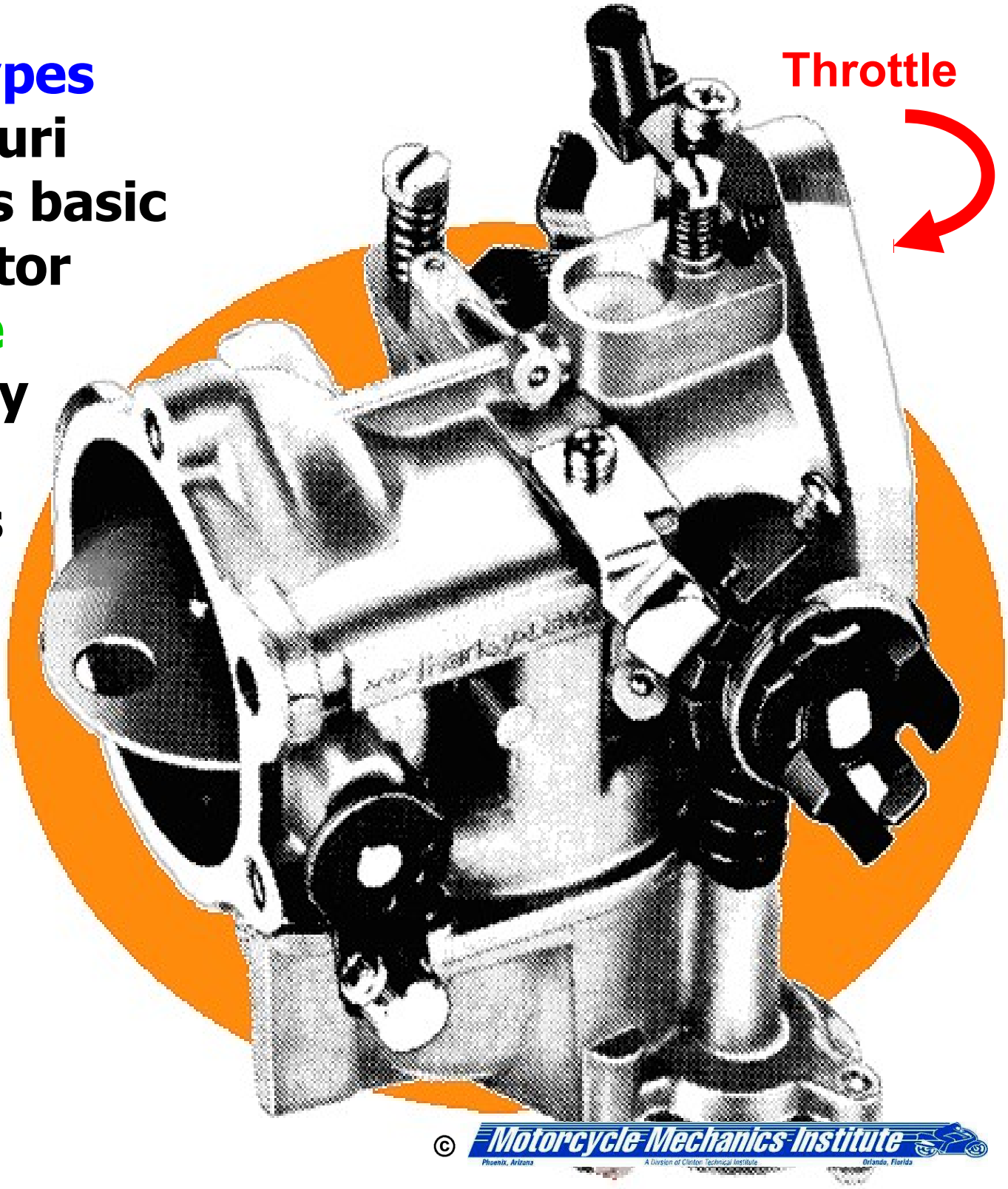
H. Mounting styles

1. Flange
   a. Mounting "ears" cast in
   b. Bolts to the manifold
   c. Not well insulated from heat, vibration
2. Spigot
   a. Carb fits into rubber extension of manifold
   b. Most common
3. Clamp-on
   a. Carb body has integral clamp
   b. Older design

III. Carburetor Types

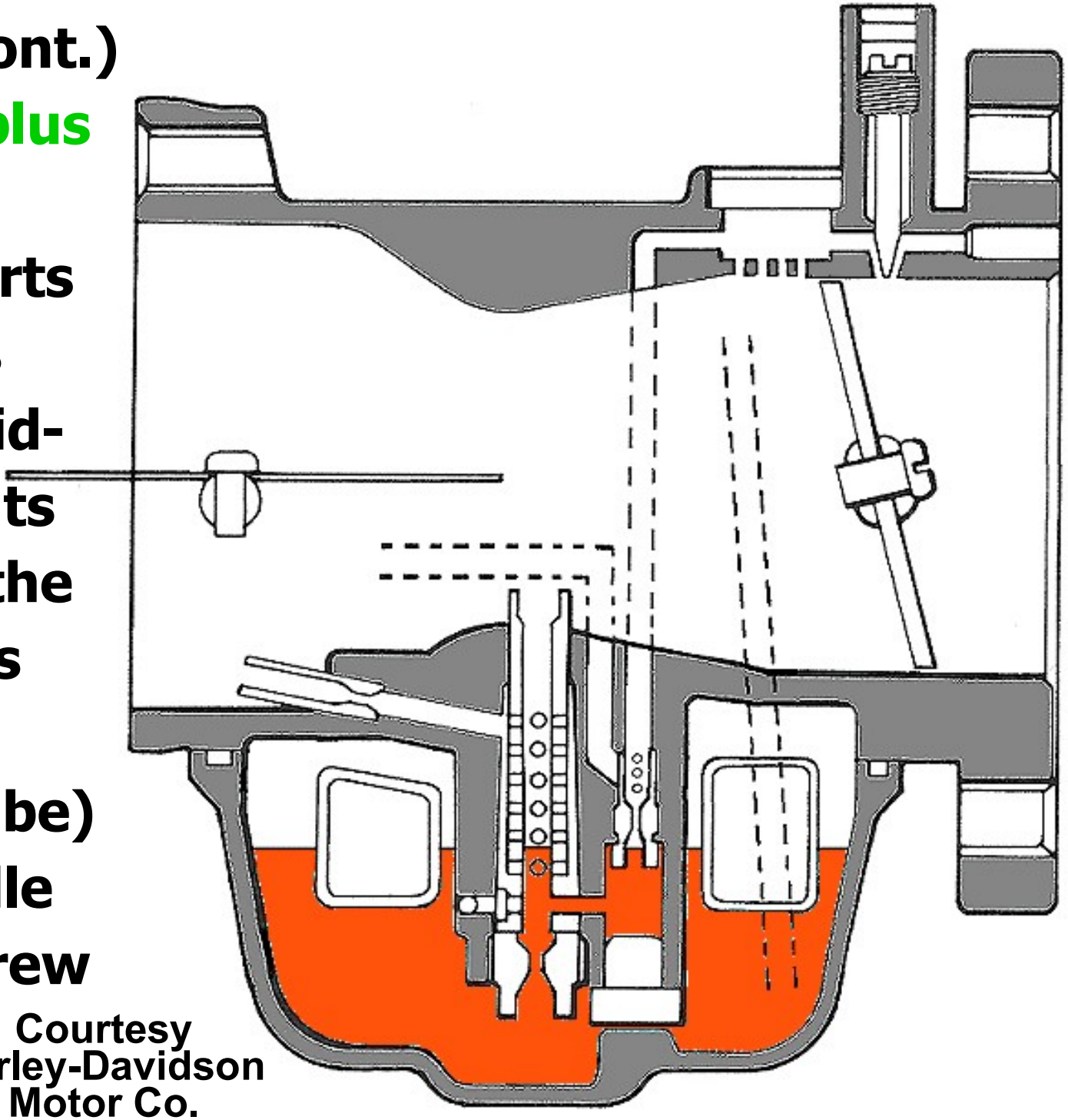
A. Fixed venturi

1. Same as basic carburetor
2. No slide
3. Butterfly throttle controls airflow



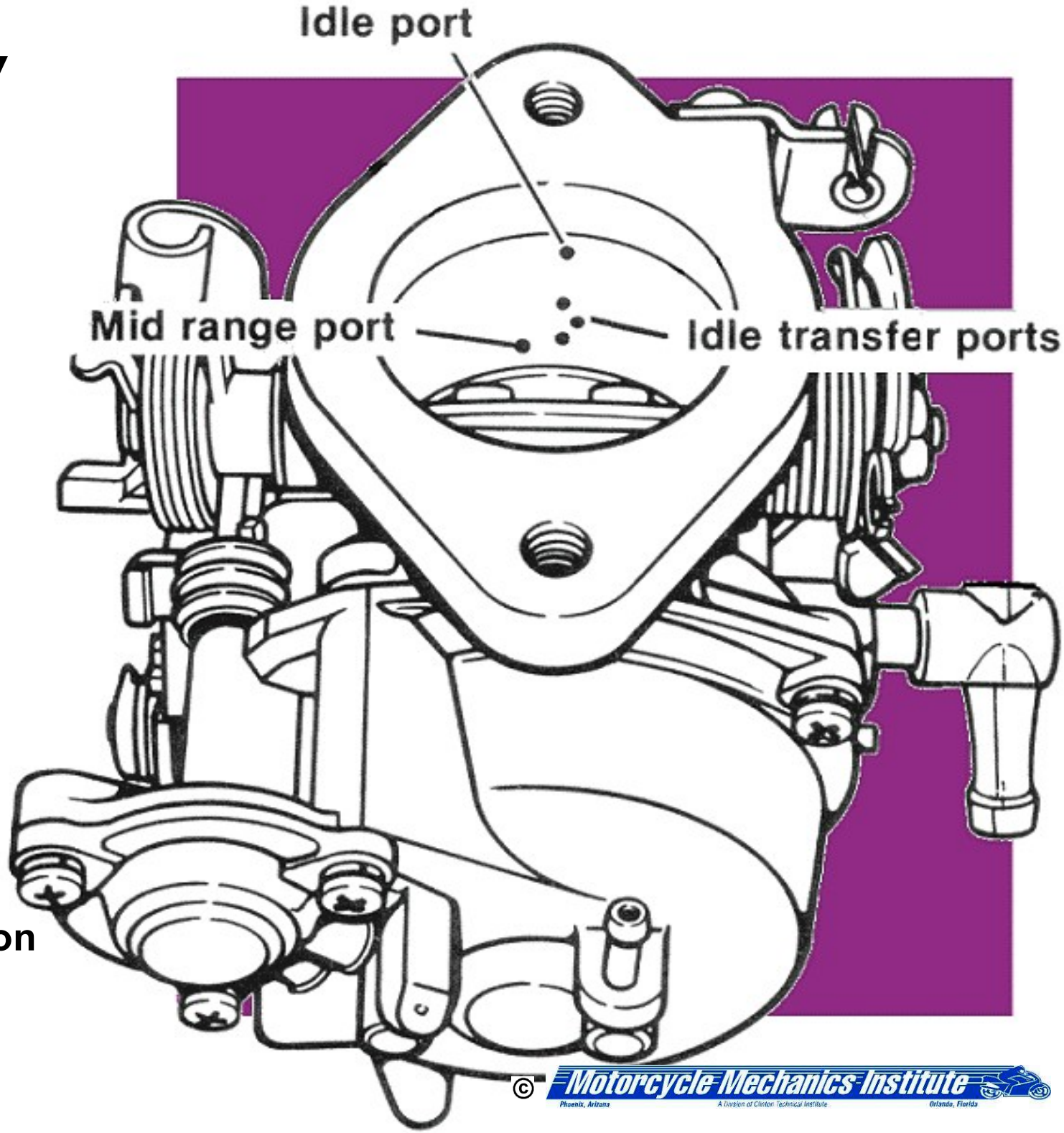
(Fixed venturi, cont.)

4. 3 circuits (plus transfer)
5. Transfer ports
6. 2 air bleeds (idle and mid-range circuits share one, the larger one is called an emulsion tube)
7. Fuel type idle mixture screw



Courtesy
Harley-Davidson
Motor Co.

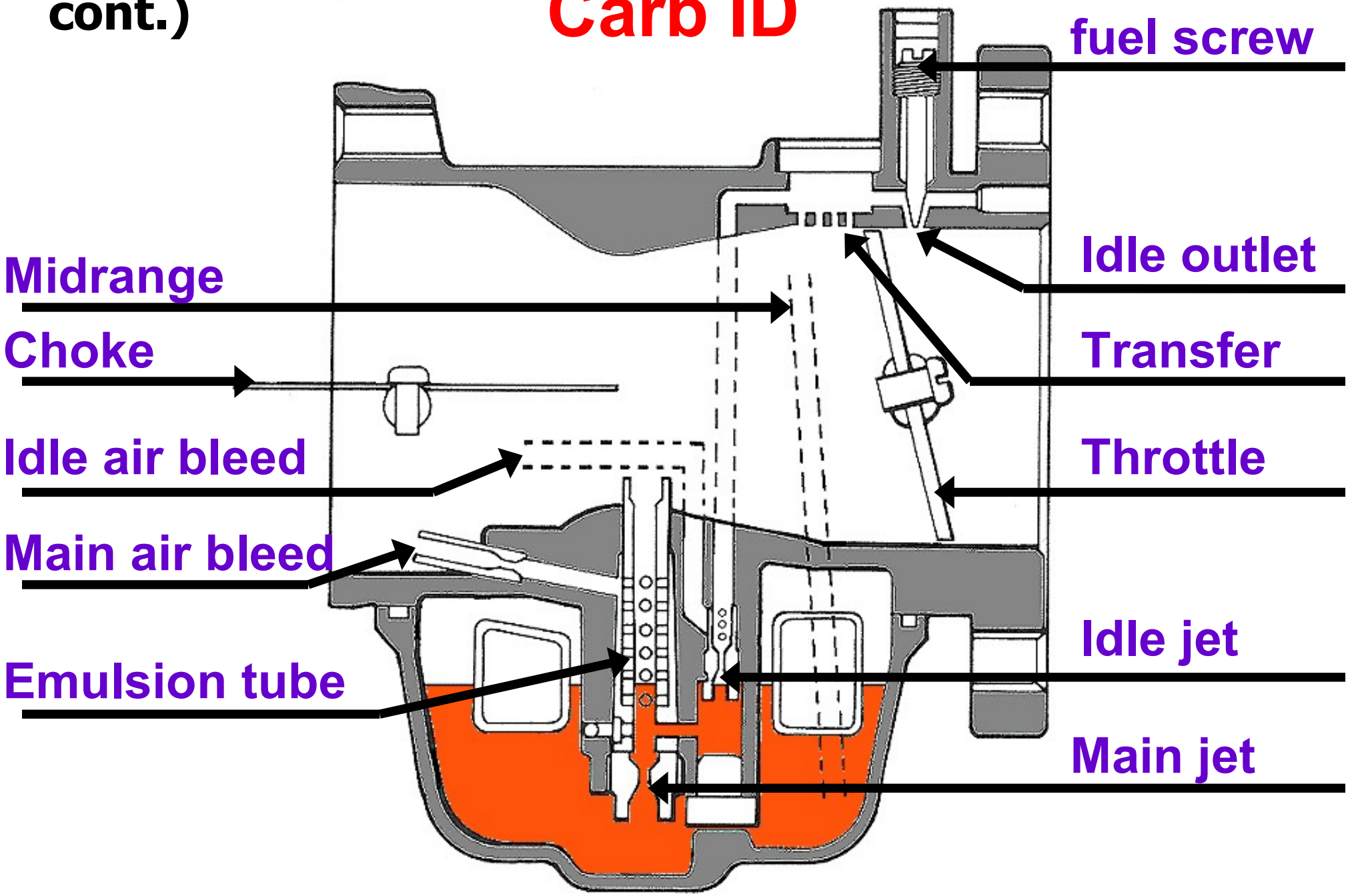
(Fixed venturi, cont.)



Courtesy
Harley-Davidson
Motor Co.

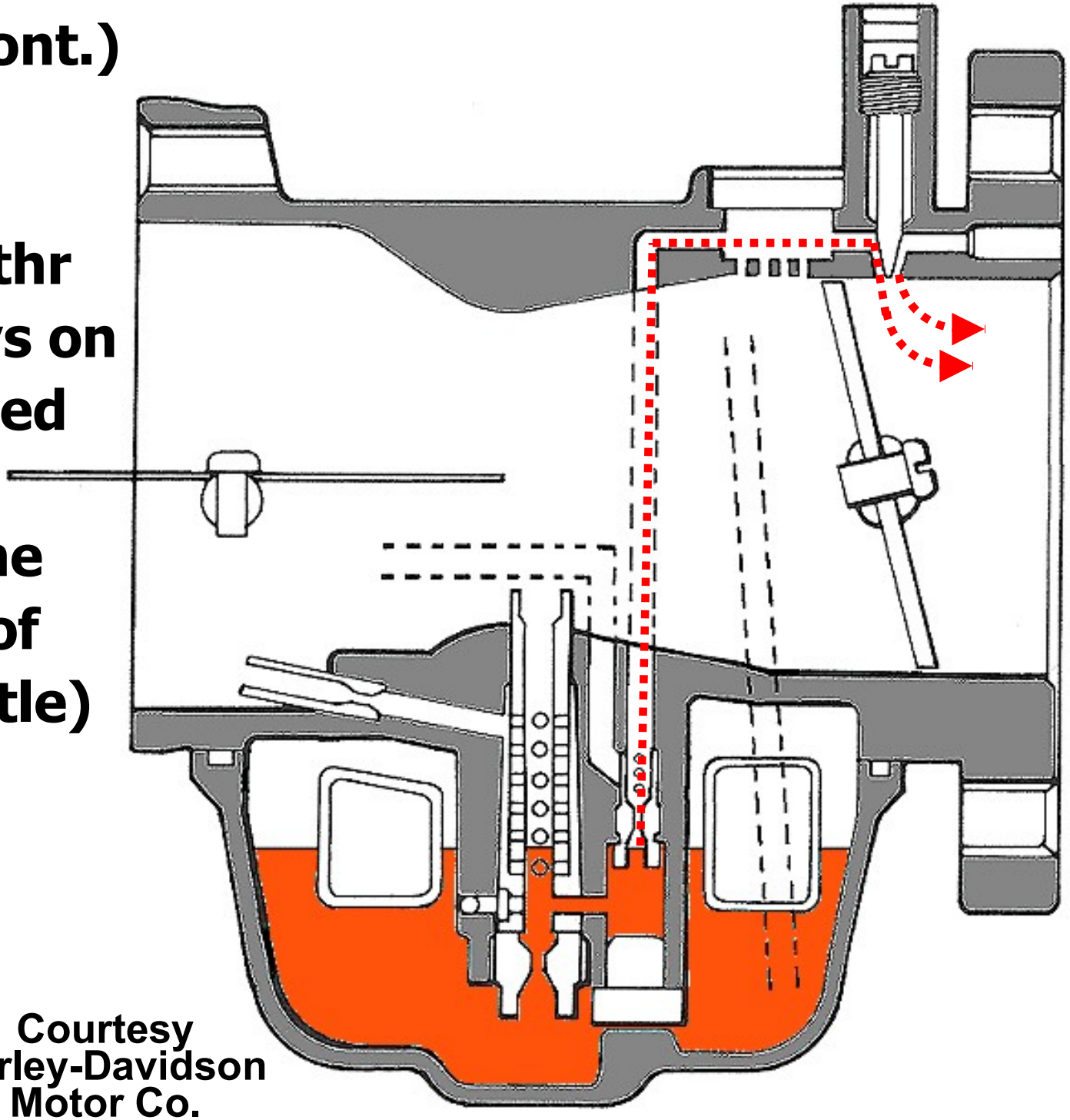
(Fixed venturi, cont.)

Carb ID



(Fixed venturi, cont.)

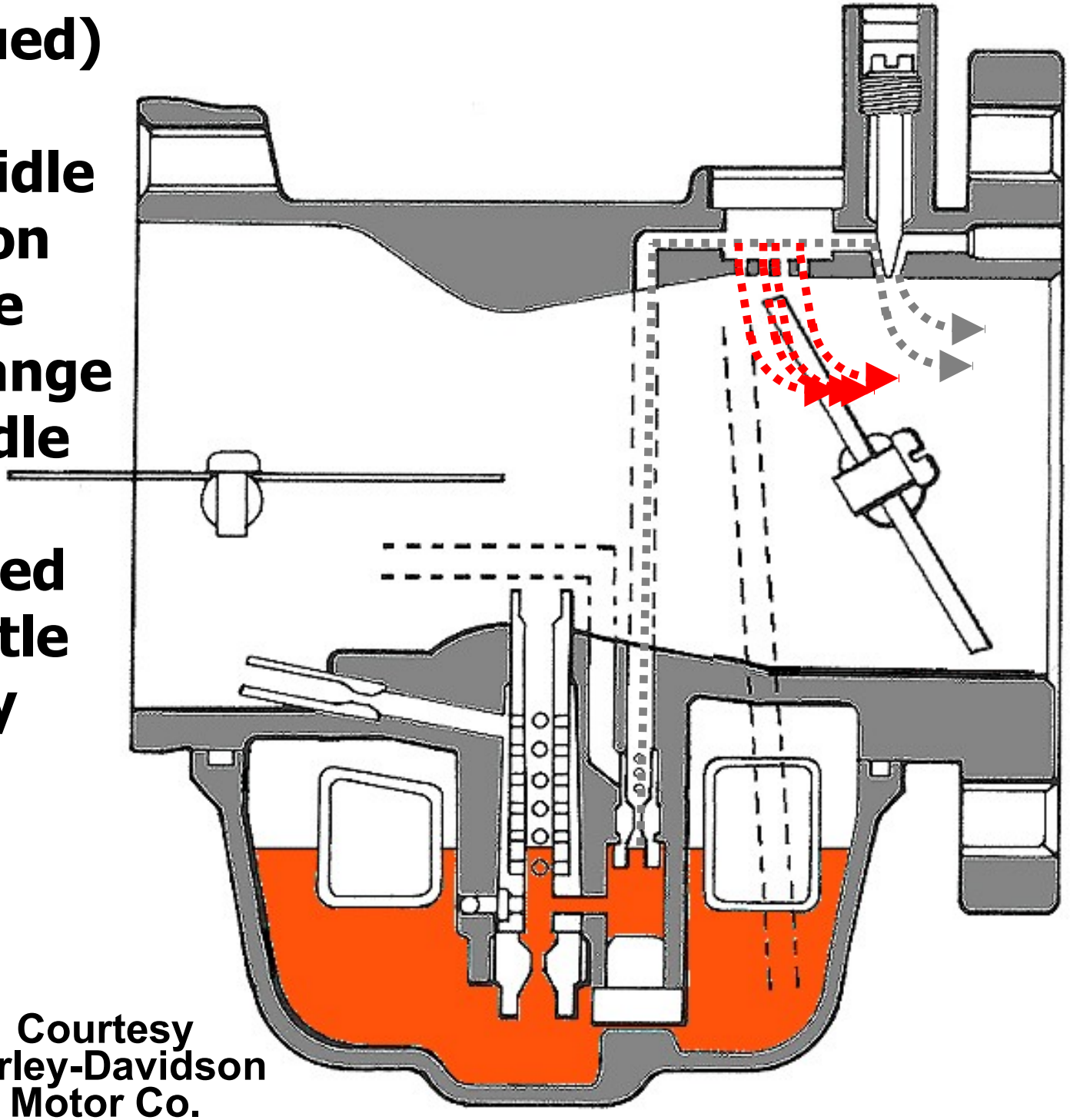
8. Circuits
   a. Idle
      1) 0-$^{1}/_{4}$ thr
      2) Always on (located on engine side of throttle)



Courtesy
Harley-Davidson
Motor Co.

(Circuits, continued)

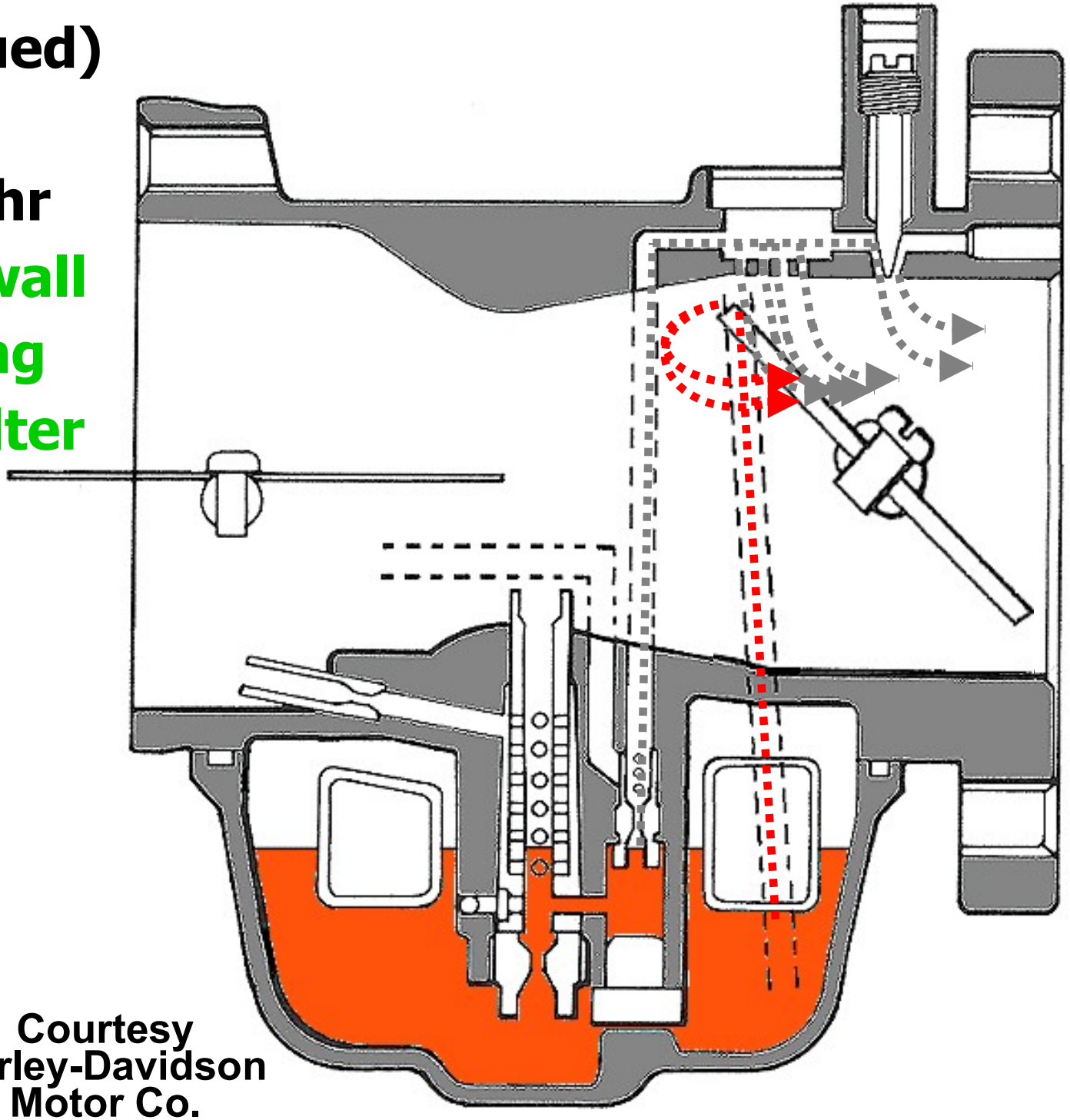
- b. Transfer
  - 1) Just off idle
  - 2) Transition from idle to midrange
  - 3) Fed by idle circuit
  - 4) Uncovered by throttle butterfly
  - 5) Staged



Courtesy
Harley-Davidson
Motor Co.

(Circuits, continued)

- c. Midrange
  - 1) $^1/_4$-$^3/_4$ thr
  - 2) Port in wall of casting on air filter side of throttle



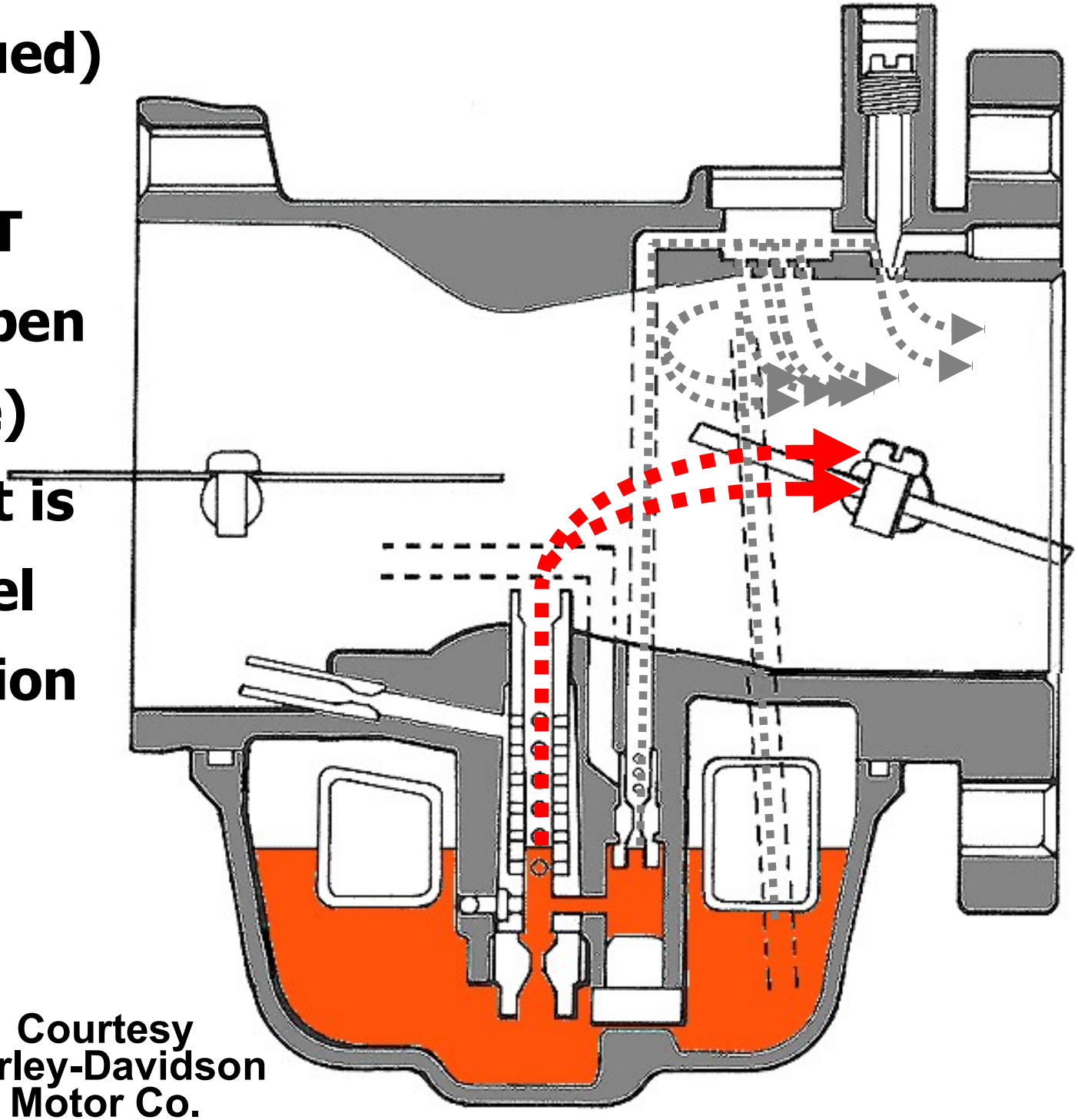
Courtesy
Harley-Davidson
Motor Co.

(Circuits, continued)

d. Main

1) $^{3}/_{4}$-WOT (wide open throttle)

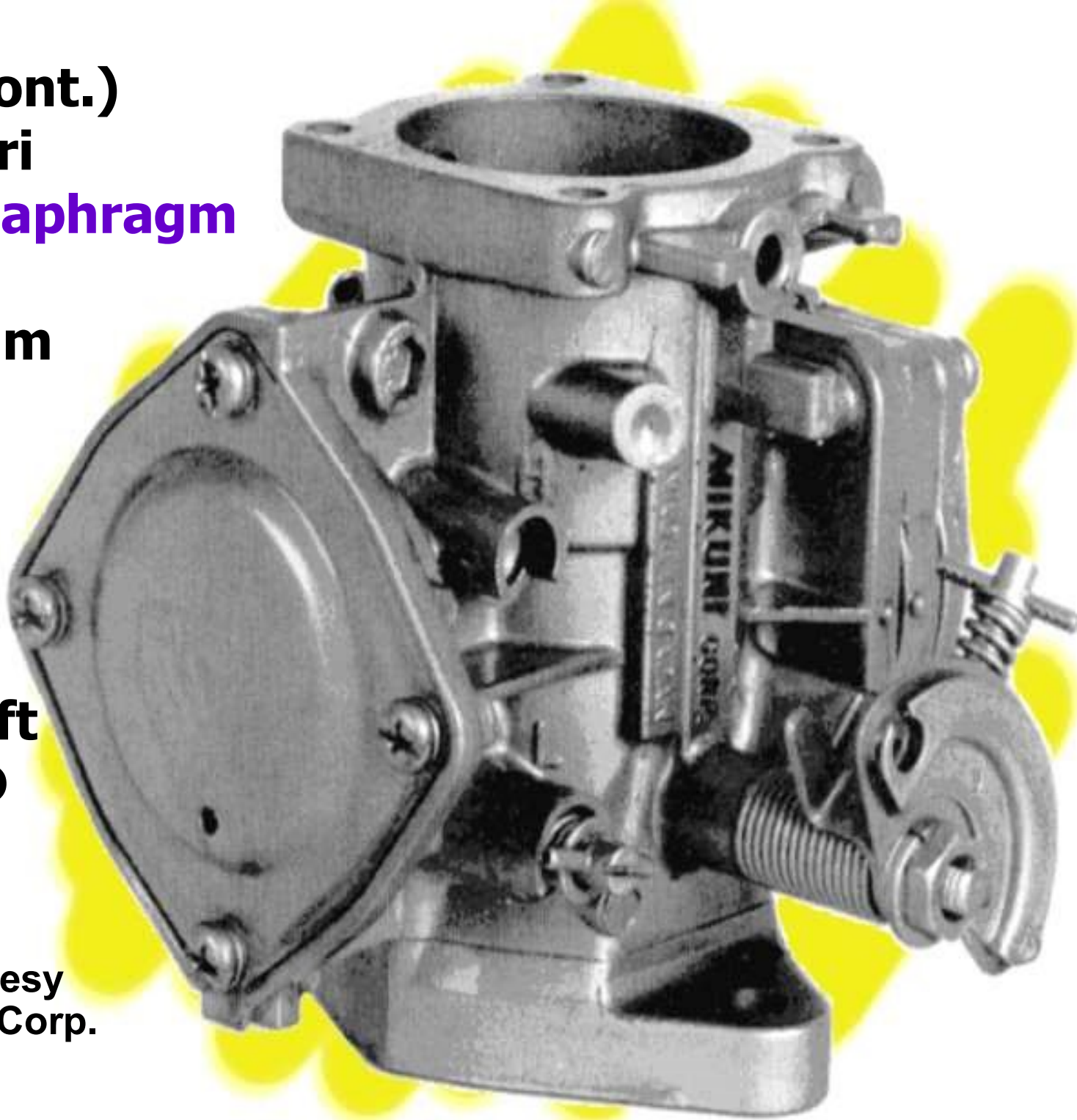
2) Main jet is final fuel restriction



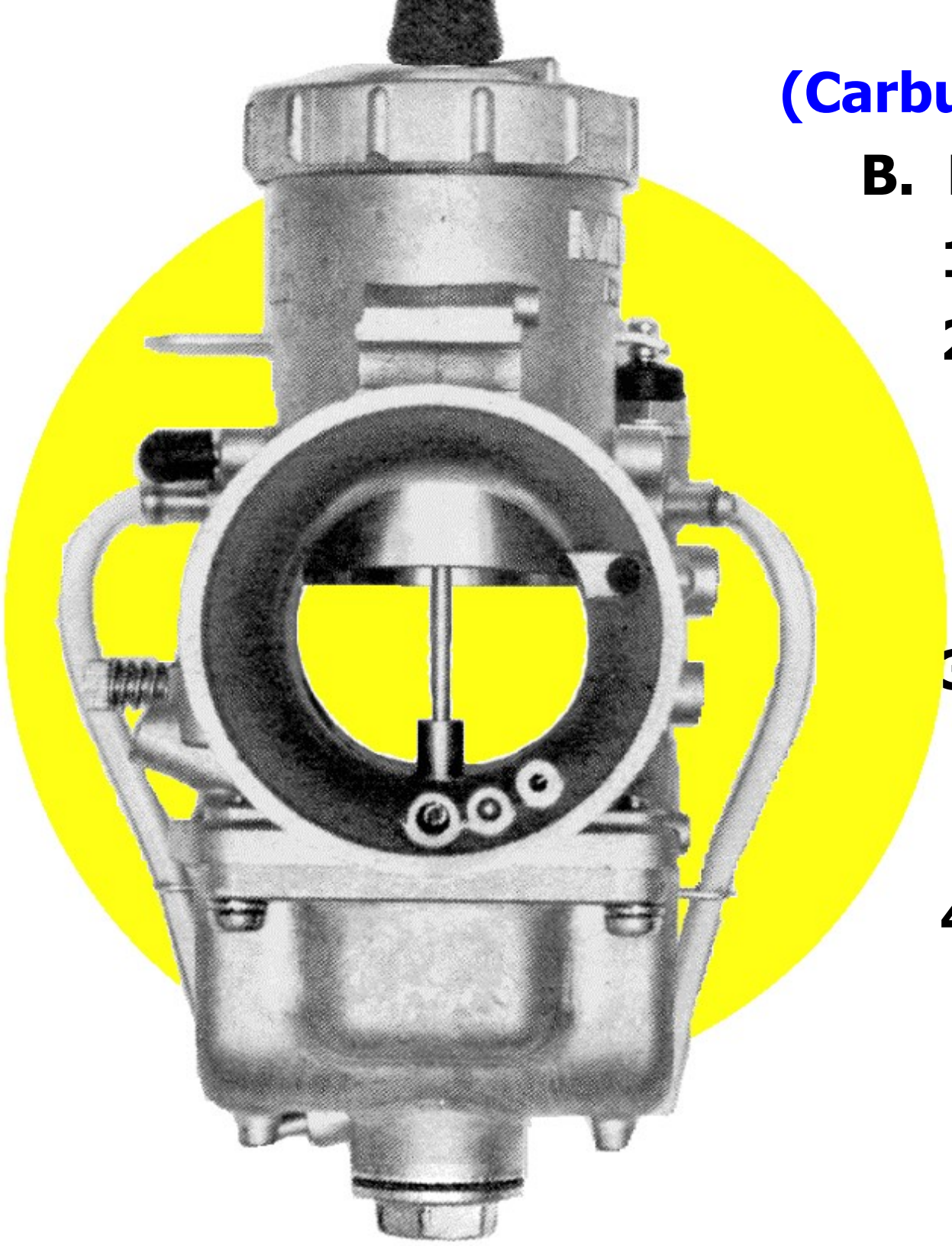
Courtesy
Harley-Davidson
Motor Co.

(Fixed venturi, cont.)

9. Fixed venturi variation: diaphragm type
   a. Diaphragm pump instead of float bowl
   b. Personal watercraft
   c. Early H-D



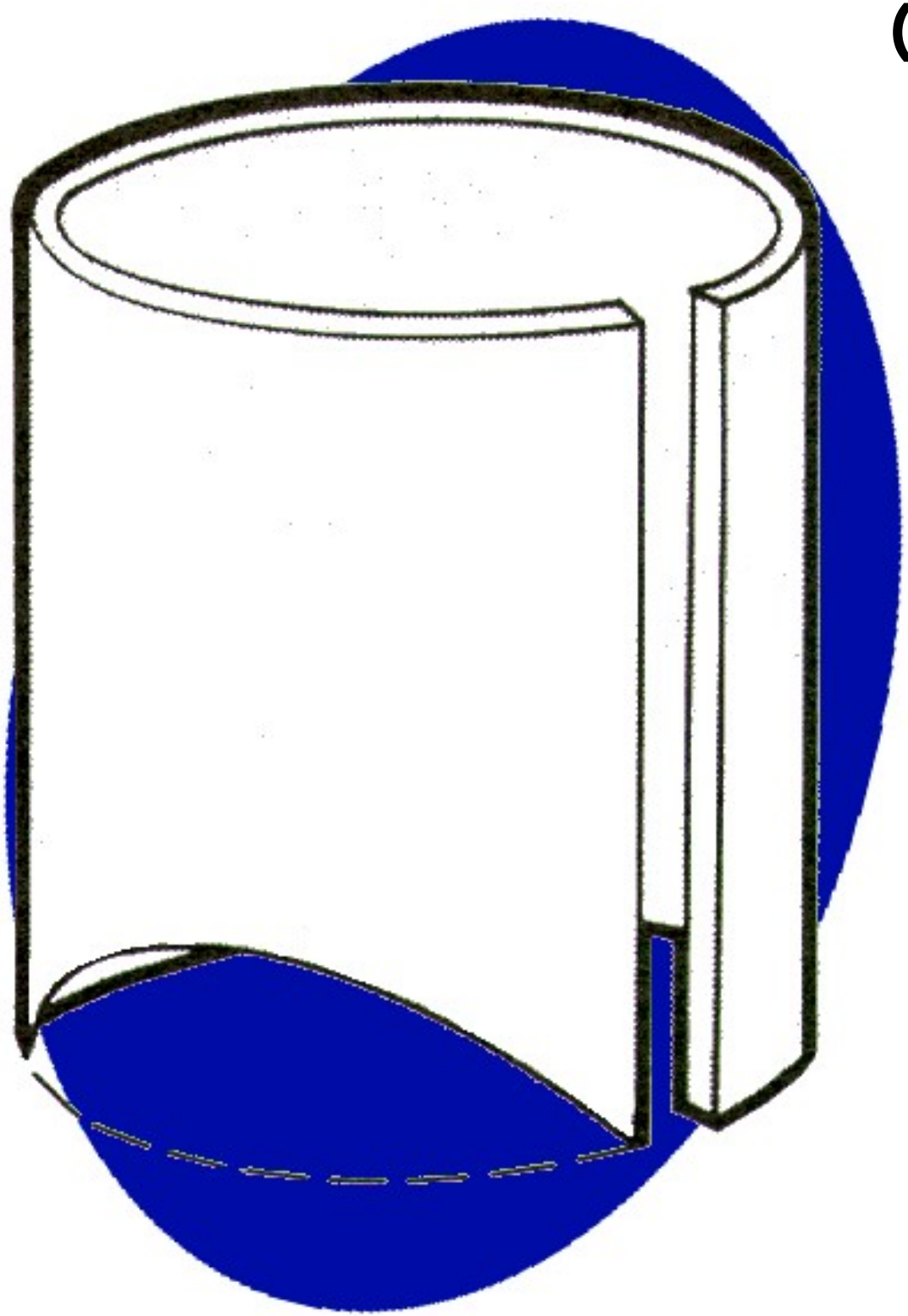
Courtesy
Mikuni Corp.



(Carburetor Types, cont.)

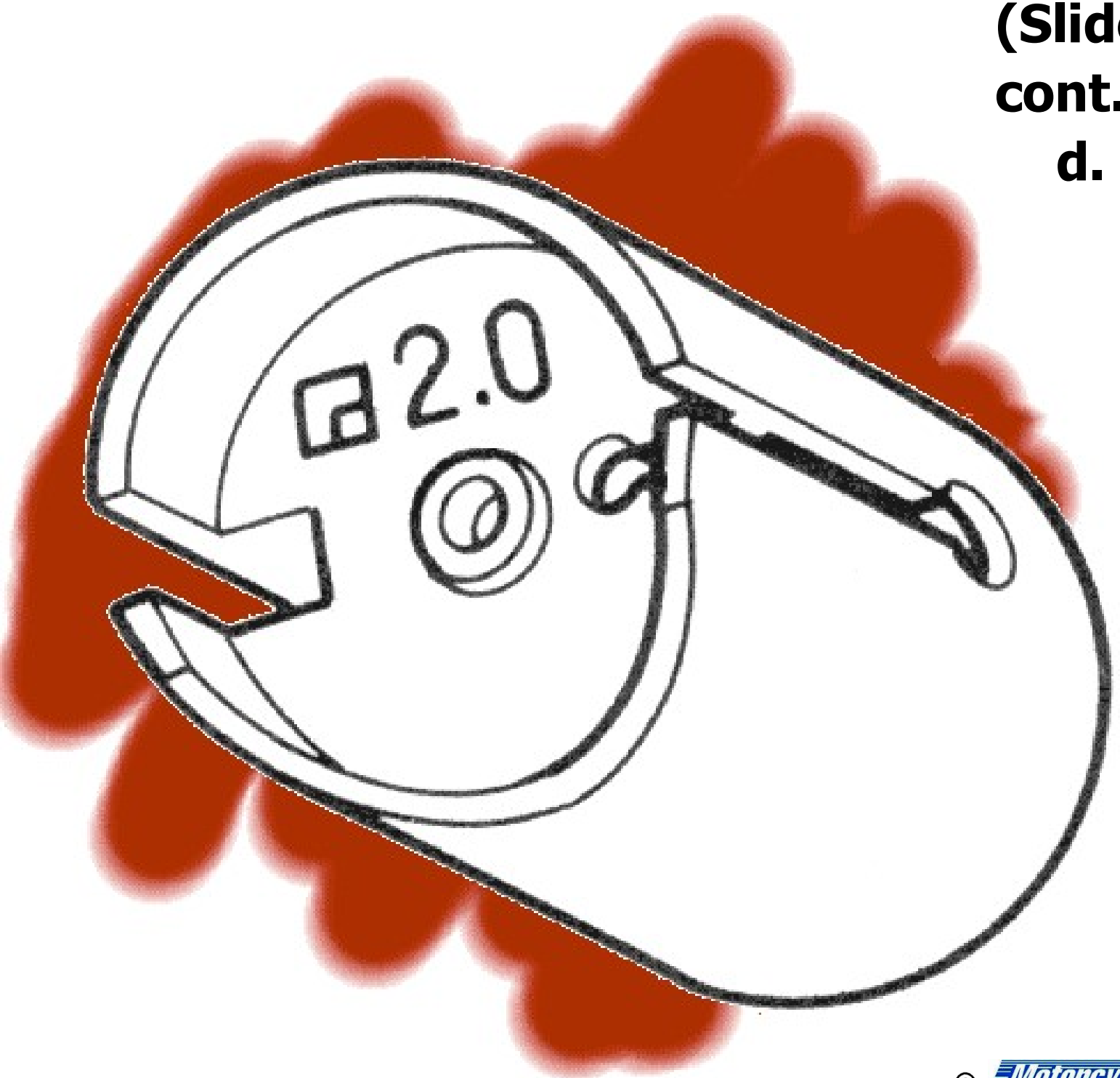
B. Mechanical slide

1. **Slide type throttle**
2. **Needle jet (same as main fuel tube) is stationary in carburetor**
3. **Jet needle is attached to and moves with slide**
4. **Slide throttle controls airflow**



(Slide type throttle, cont.)

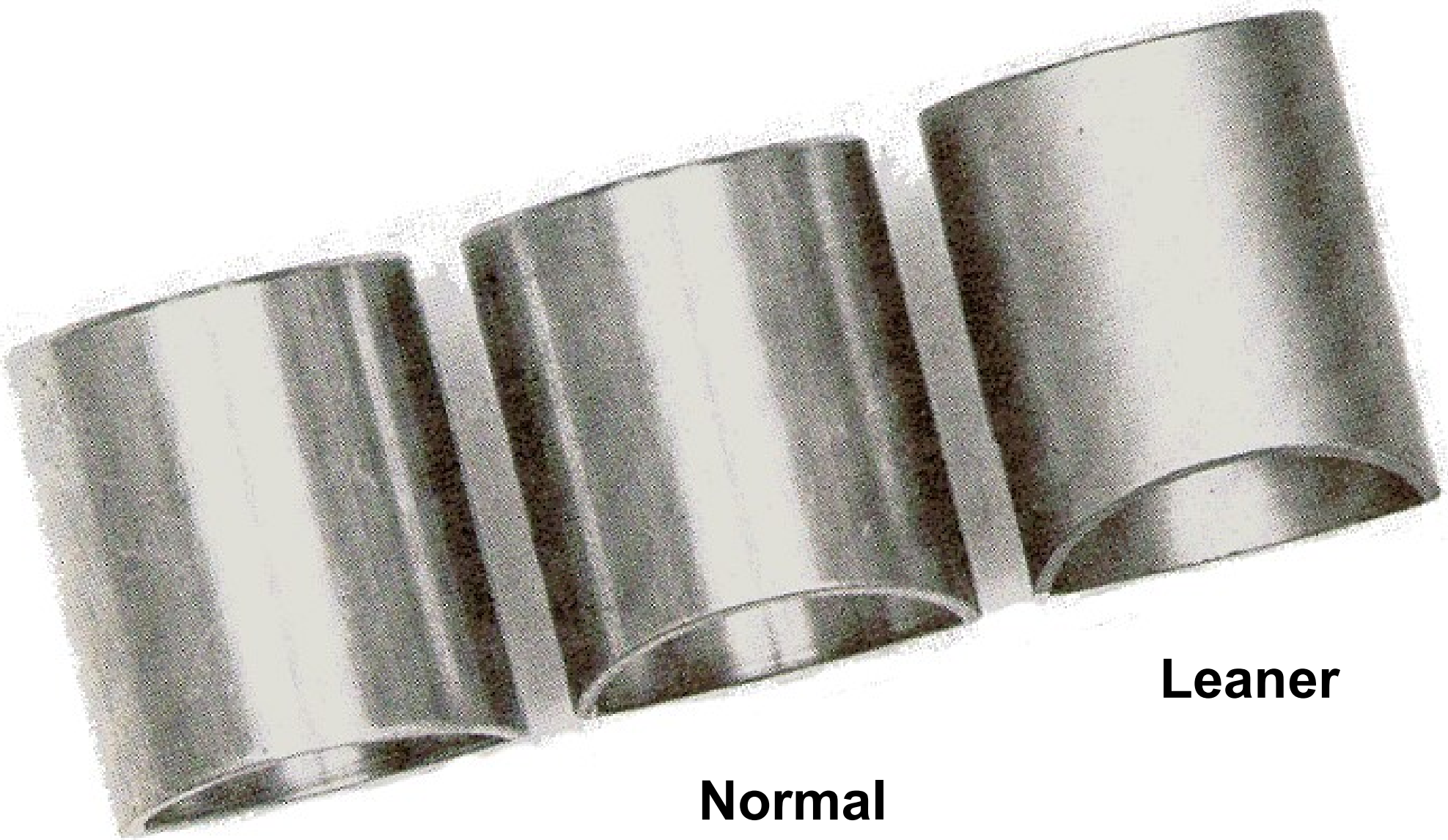
a. Mechanical slide carbs have slides with cutaway
b. Affects discharge at $^{1}/_{8}$-$^{1}/_{4}$ throttle
c. Cutaway faces air filter side of carburetor



(Slide type throttle, cont.)

- **d. Cutaway size often marked on bottom**
  1) **Larger number = leaner**
  2) **Smaller number = richer**

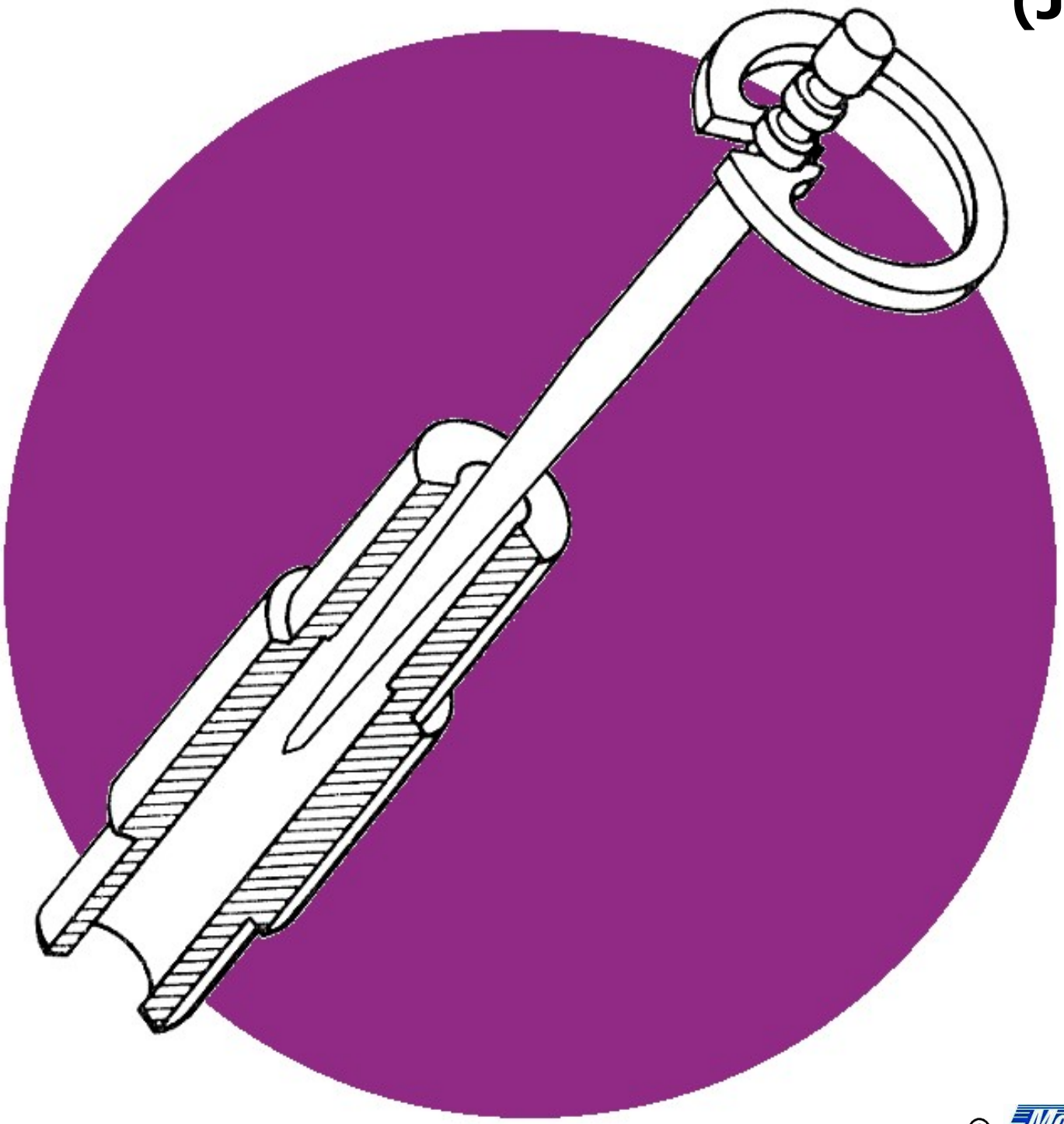
(Slide type throttle, cont.)



(Needle jet, cont.)

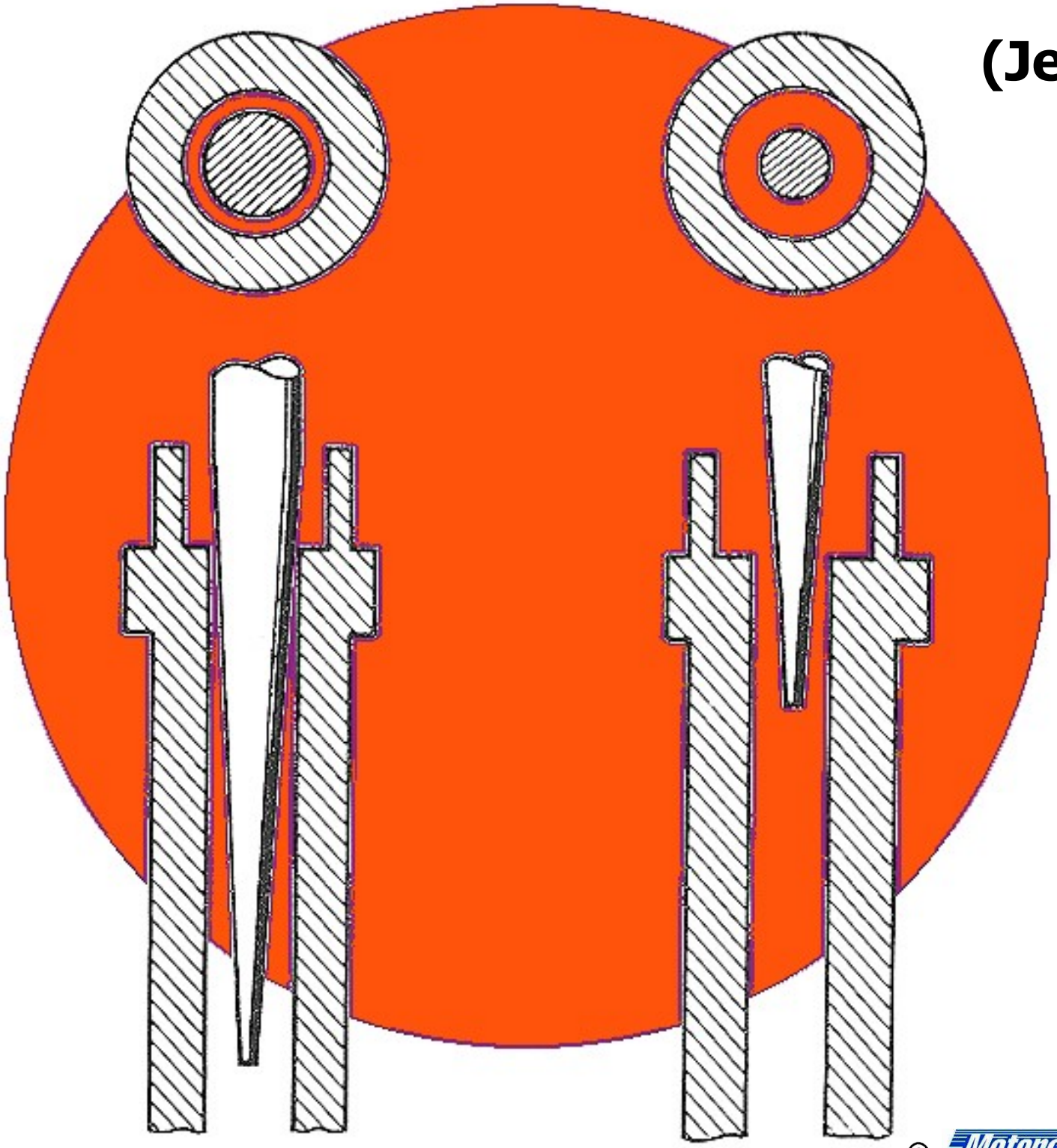
a. Three types
   1) Primary
      a) Hooded
      b) Often just one hole
      c) 2-strokes, racing carbs
   2) Bleed
      a) No hood
      b) Many holes
      c) 4-strokes
   3) Primary/bleed (combined attributes)

Shown with main jet attached



(Jet needle, cont.)

b. Taper begins at about $^{1}/_{4}$ throttle
c. Needle is attached to and moves with slide
d. Jet stays in carb casting



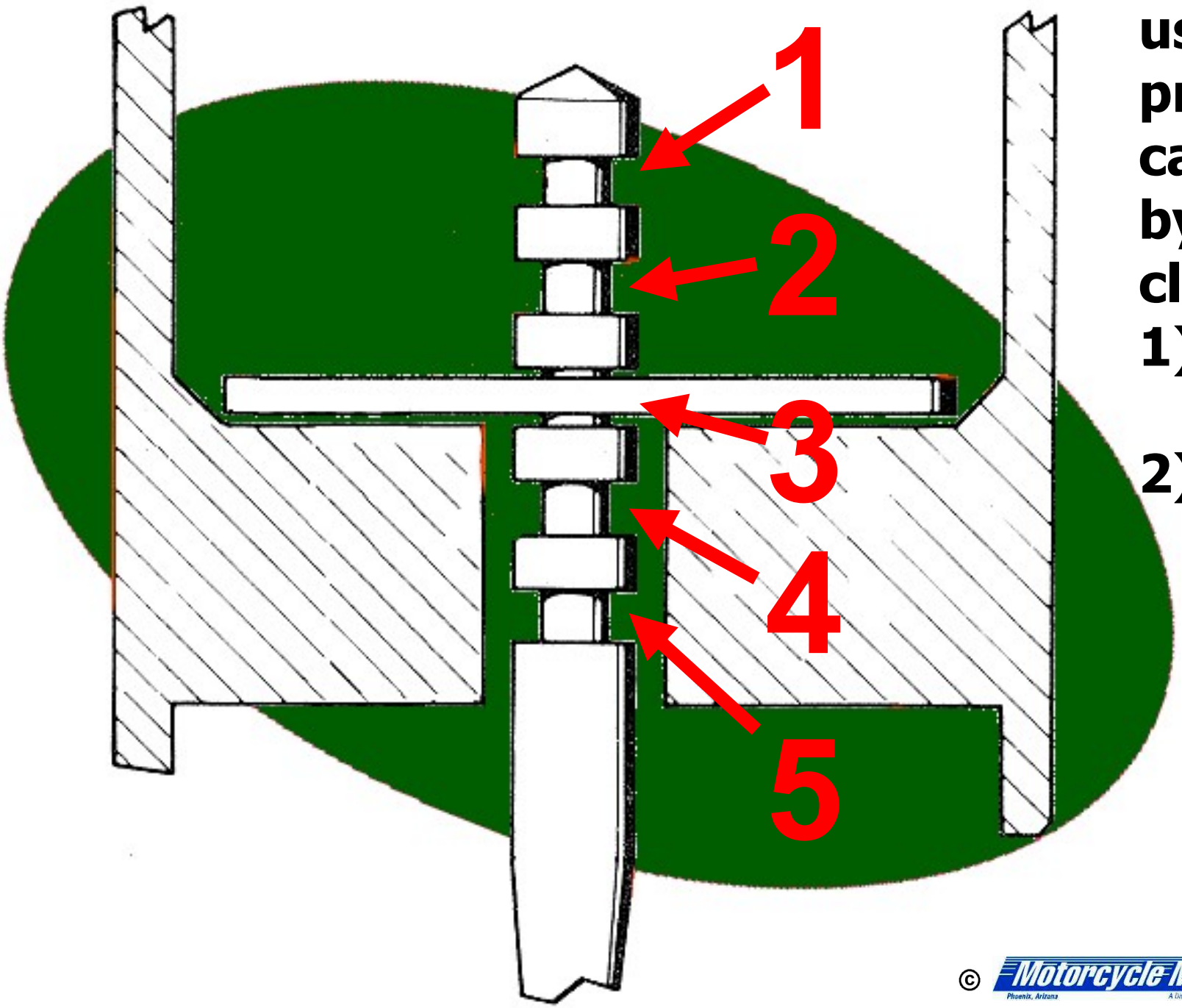
(Jet needle, cont.)

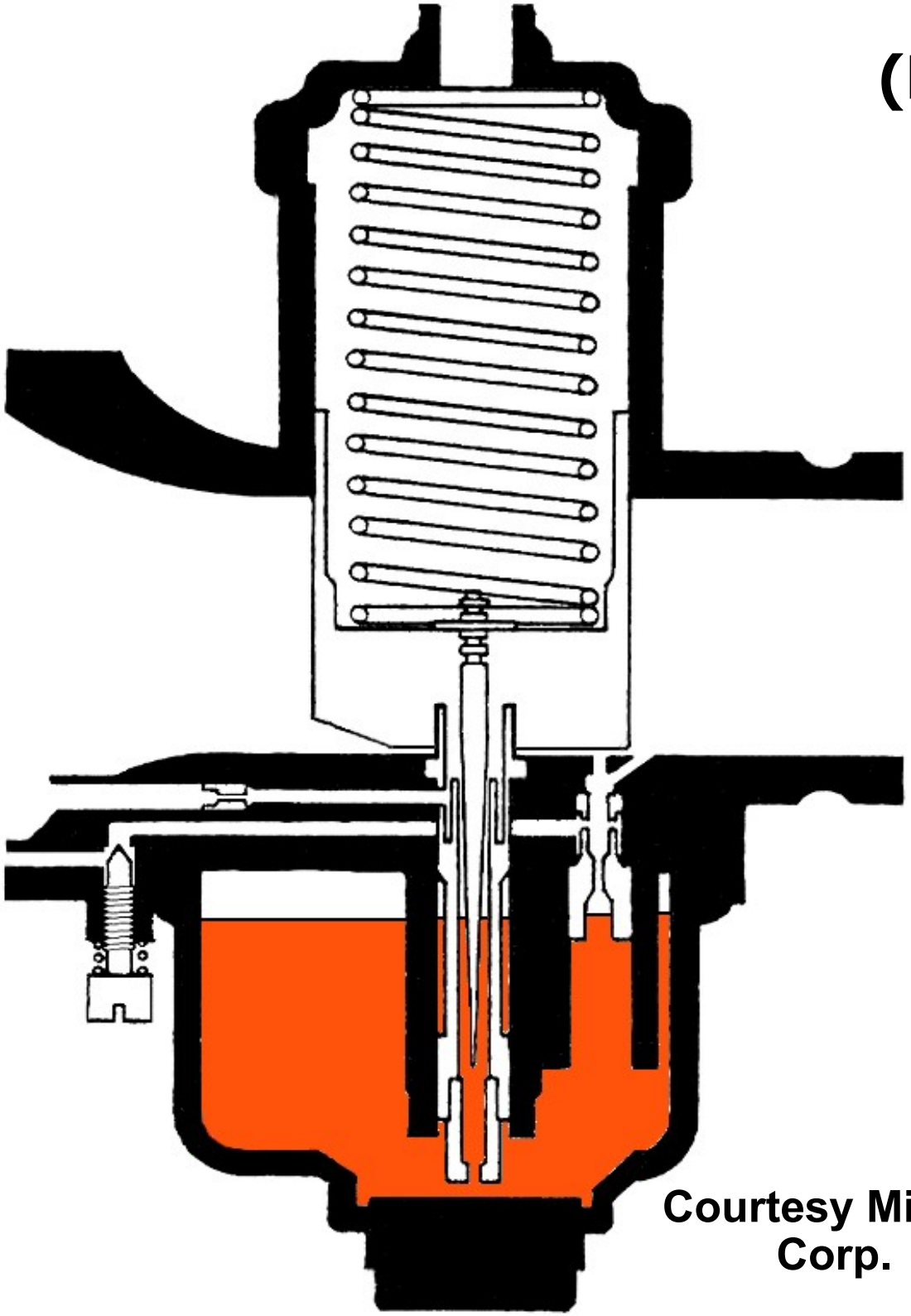
e. Flow area increases as needle is raised further

(Jet needle, cont.)

f. Needle is adjustable (on pre-emissions carburetors), by changing clip position

1) Clip up = leaner
2) Clip down = richer





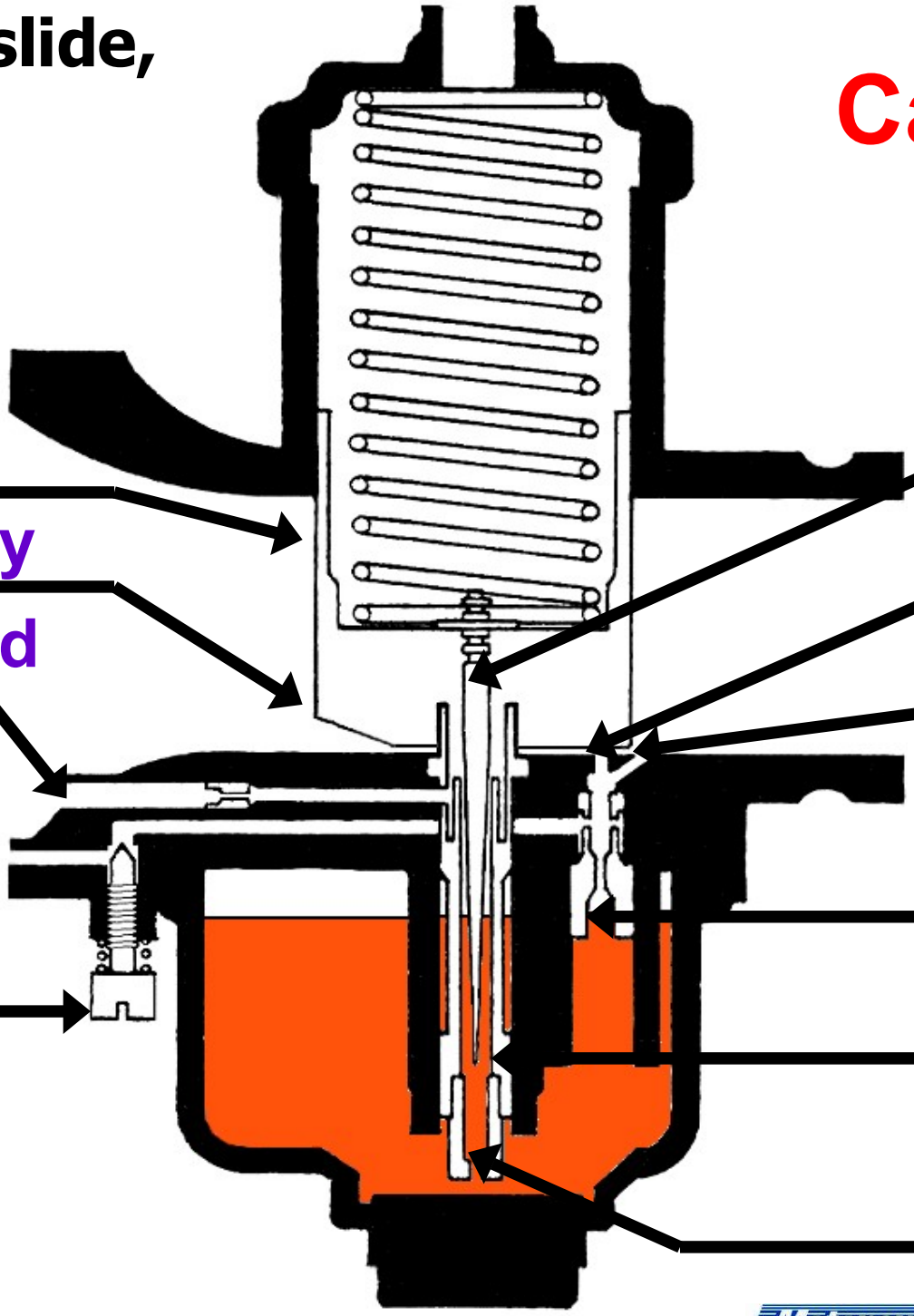
Courtesy Mikuni Corp.

(Mechanical slide, cont.)

4. 4 circuits (plus transfer)
5. Transfer ports
6. 2 air bleeds (needle jet and main circuits share one)
7. Air type idle mixture screw

(Mechanical slide, cont.)

Carb ID



Slide

Slide cutaway

Main air bleed

Idle air bleed

Idle mixture air screw

Jet needle

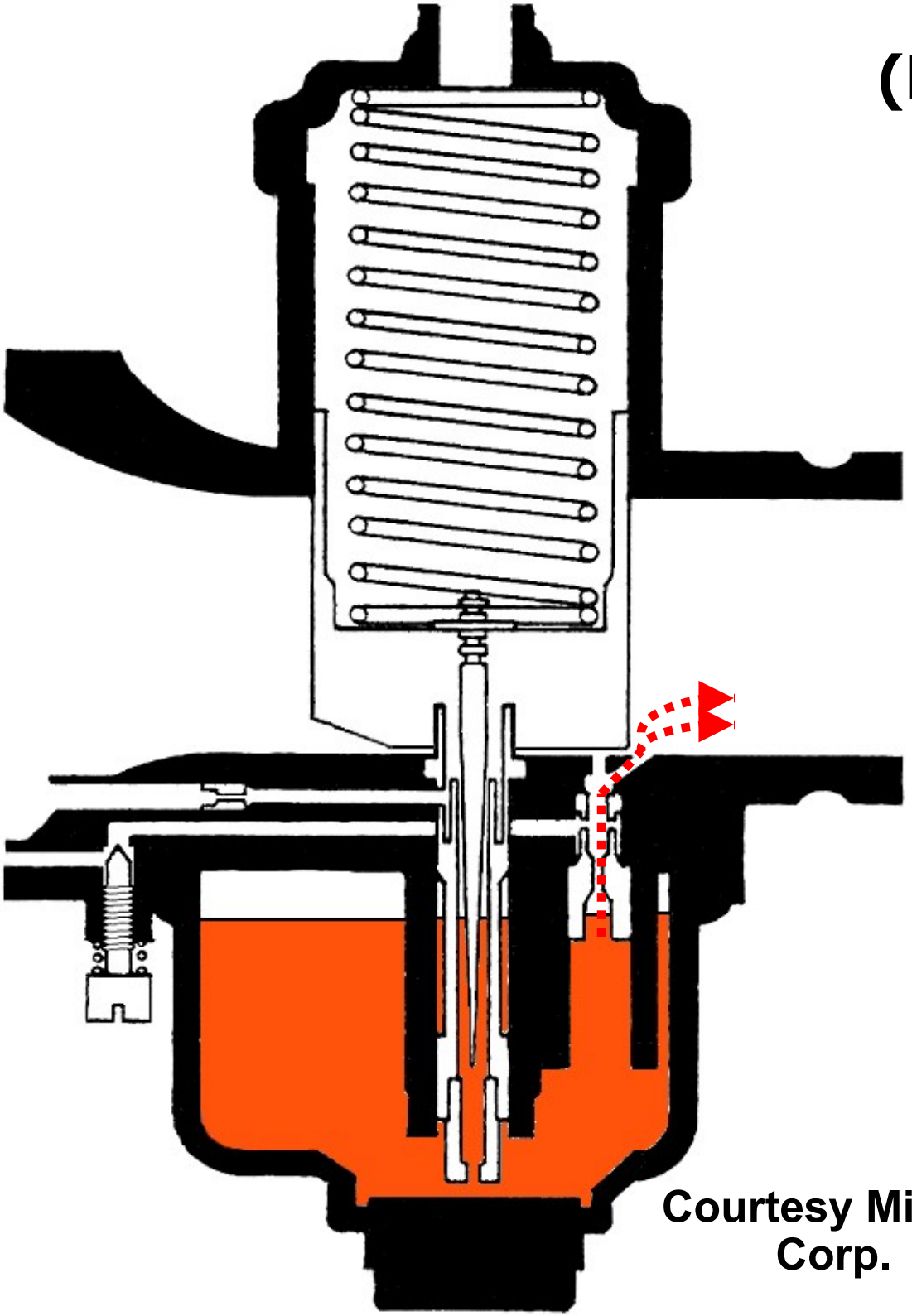
Transfer

Idle outlet

Idle jet

Needle jet

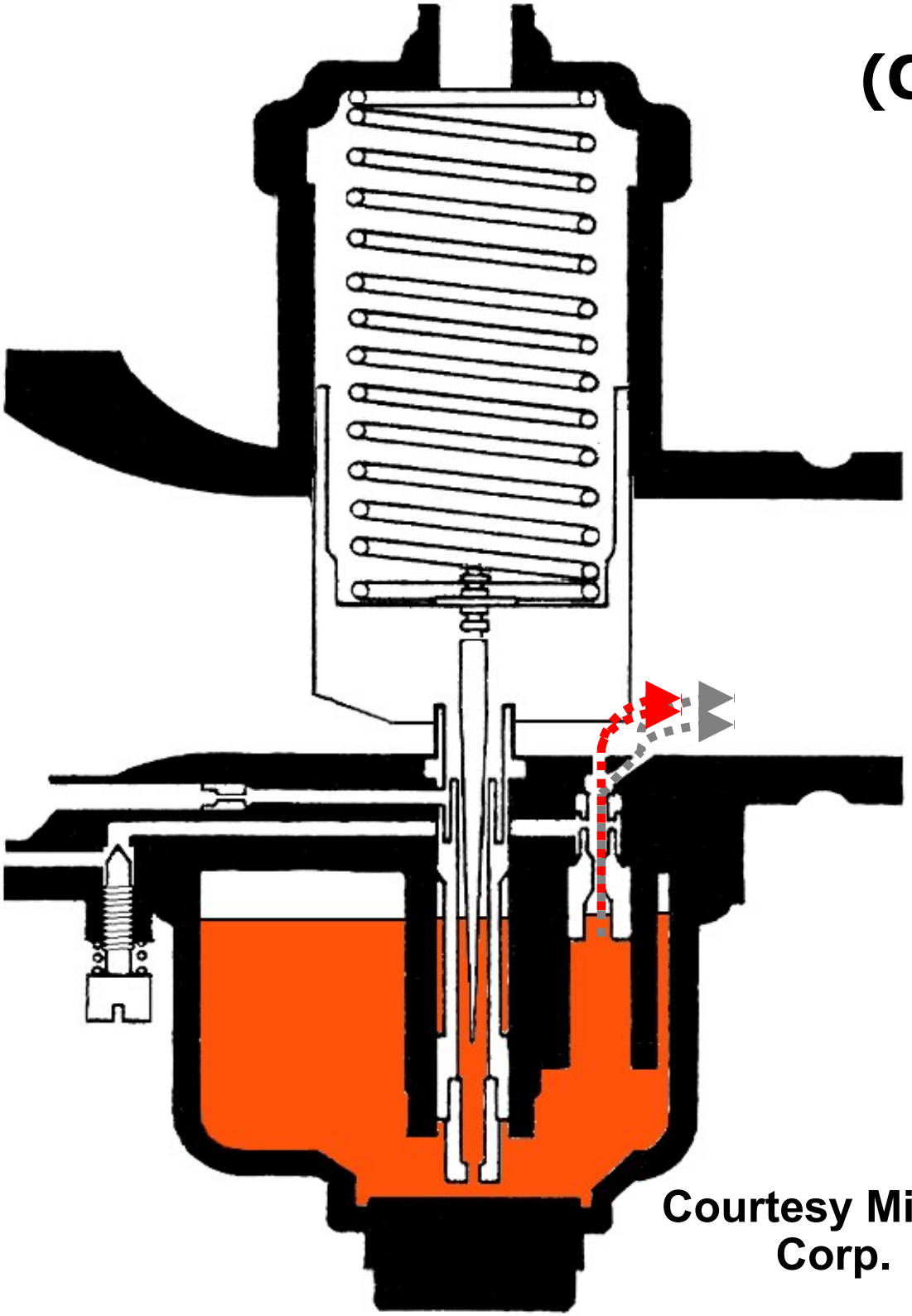
Main jet



Courtesy Mikuni Corp.

(Mechanical slide, cont.)

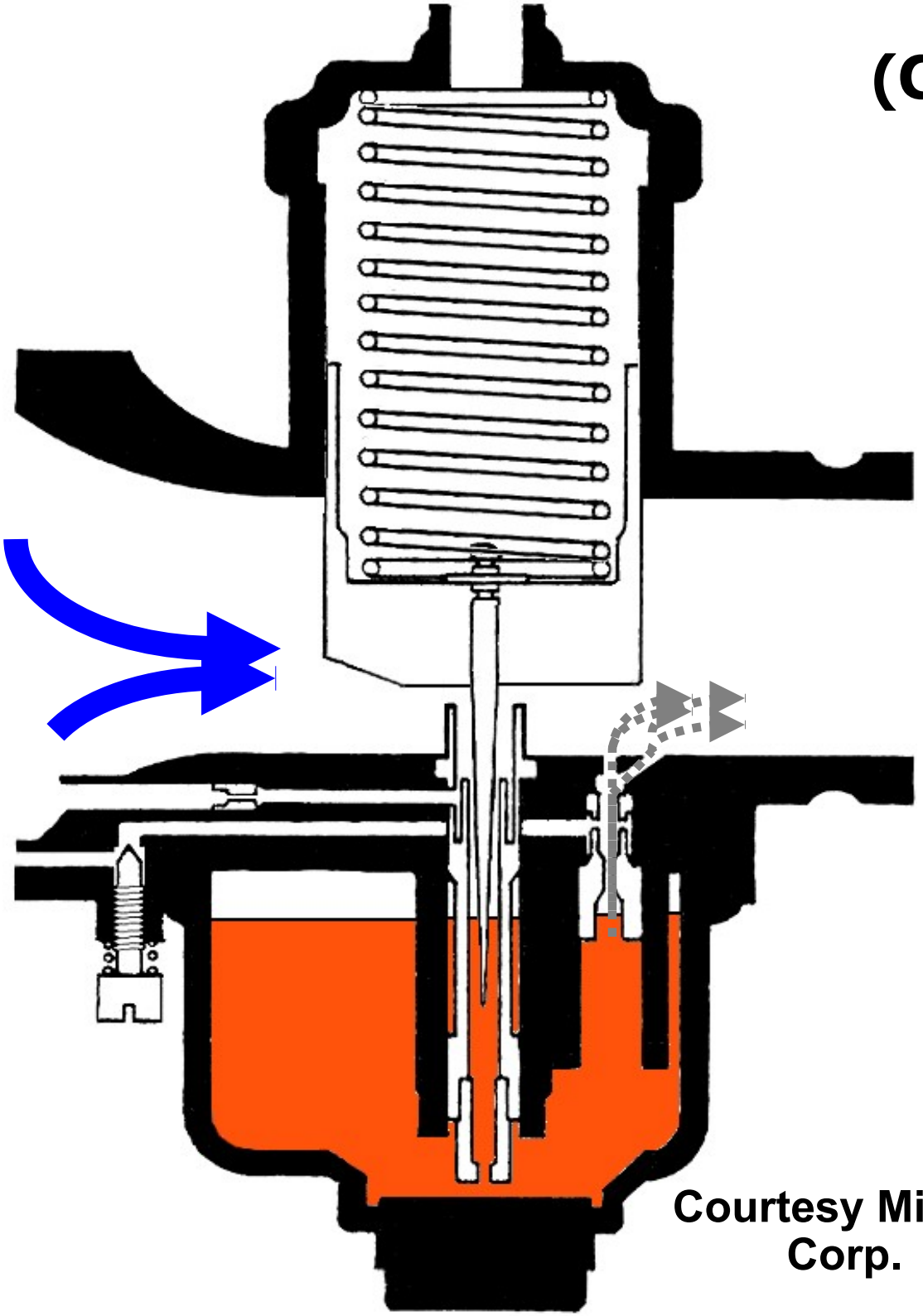
8. Circuits
   a. Idle
      1) 0-$^{1}/_{4}$ throttle
      2) Always on



Courtesy Mikuni Corp.

(Circuits, cont.)

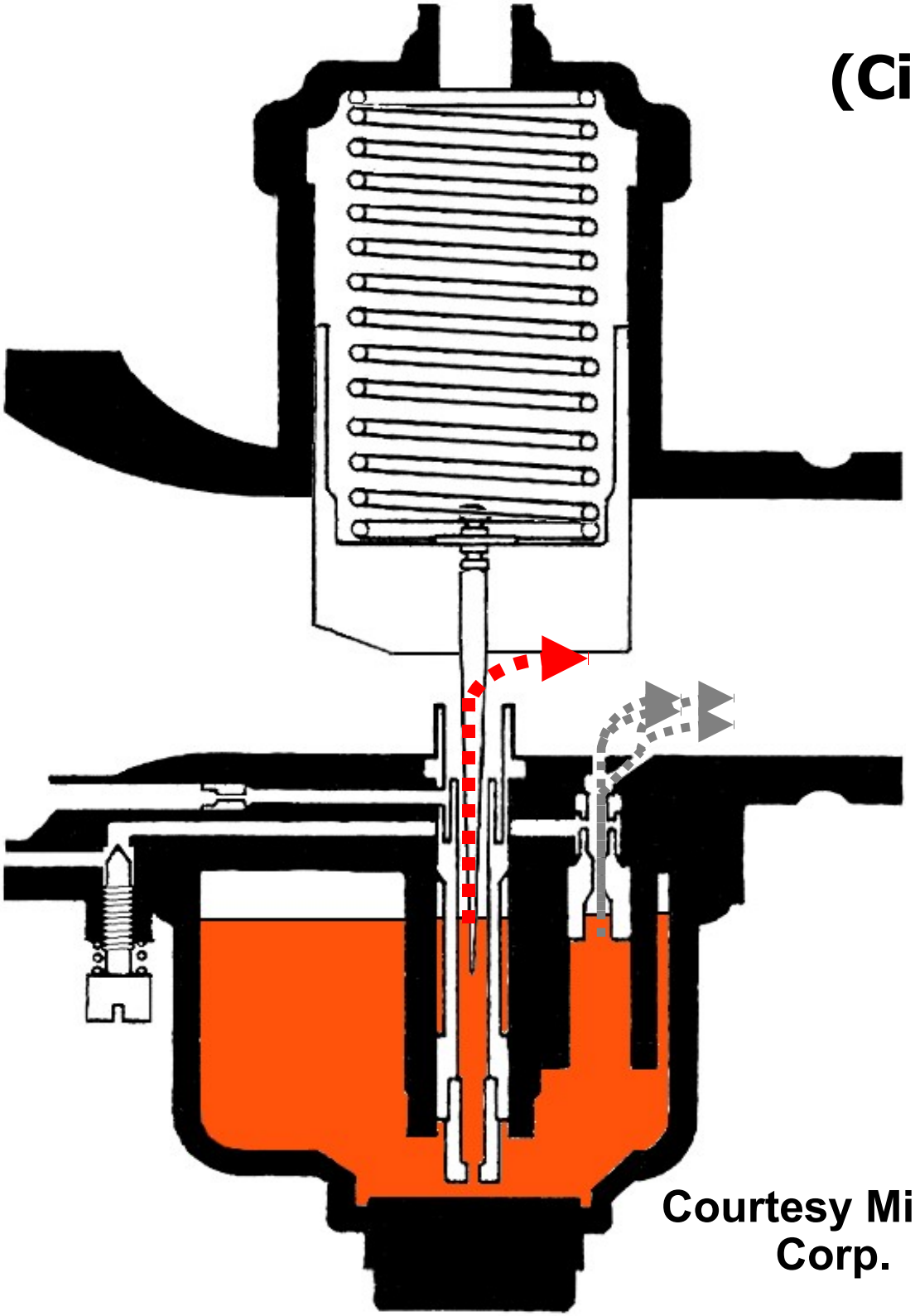
- b. Transfer (bypass)
  - 1) Just off idle
  - 2) Transition circuit
  - 3) Uncovered by slide throttle



Courtesy Mikuni Corp.

(Circuits, cont.)

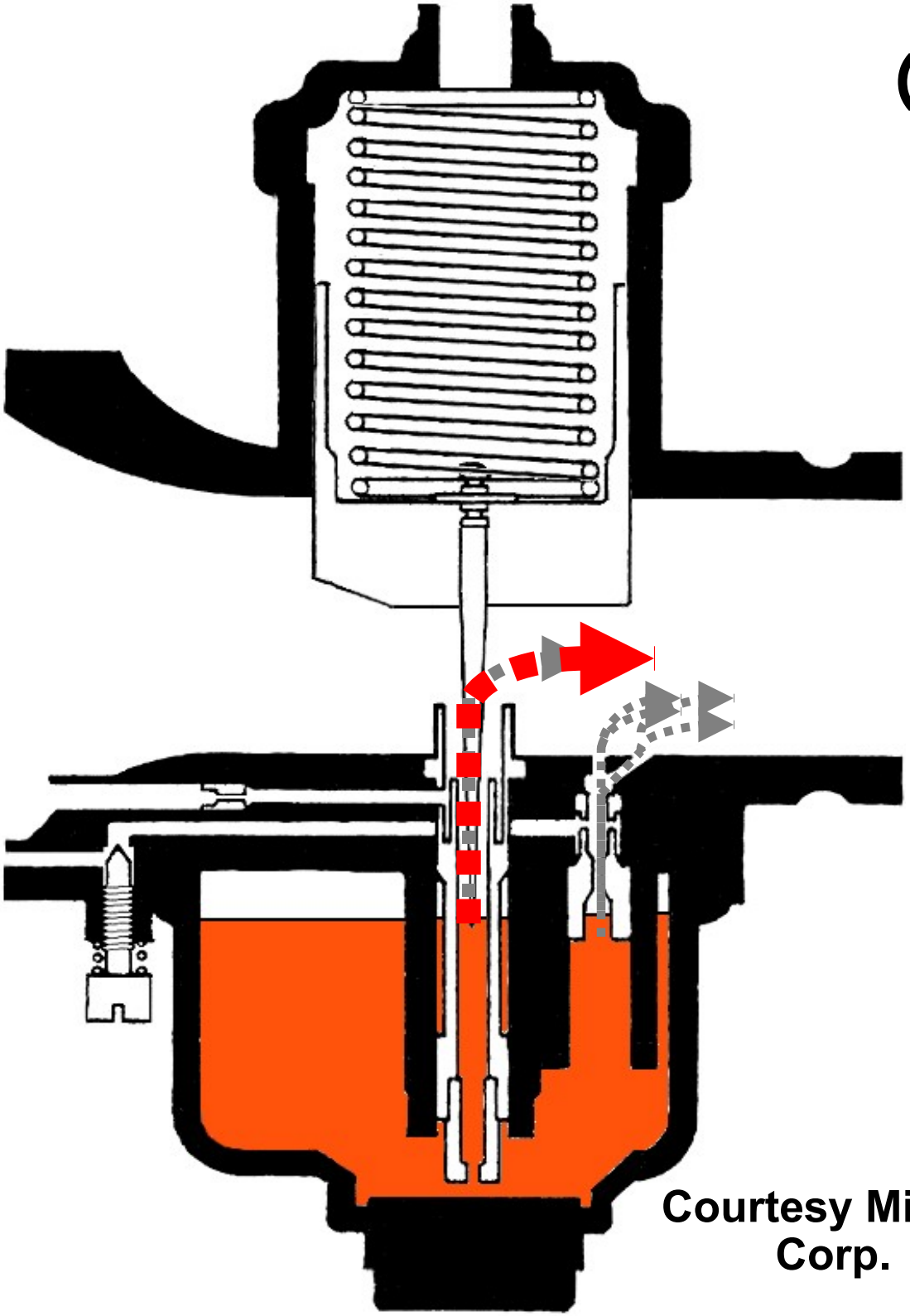
c. Slide cutaway
   1) $^{1}/_{8}$-$^{1}/_{4}$ throttle
   2) Funnel effect
   3) Transition from transfer to needle



Courtesy Mikuni Corp.

(Circuits, cont.)

- d. Needle jet
  - 1) $^{1}/_{4}$-$^{3}/_{4}$ throttle
    - a) Widest range
    - b) Most ridden
  - 2) Considered the "midrange" circuit



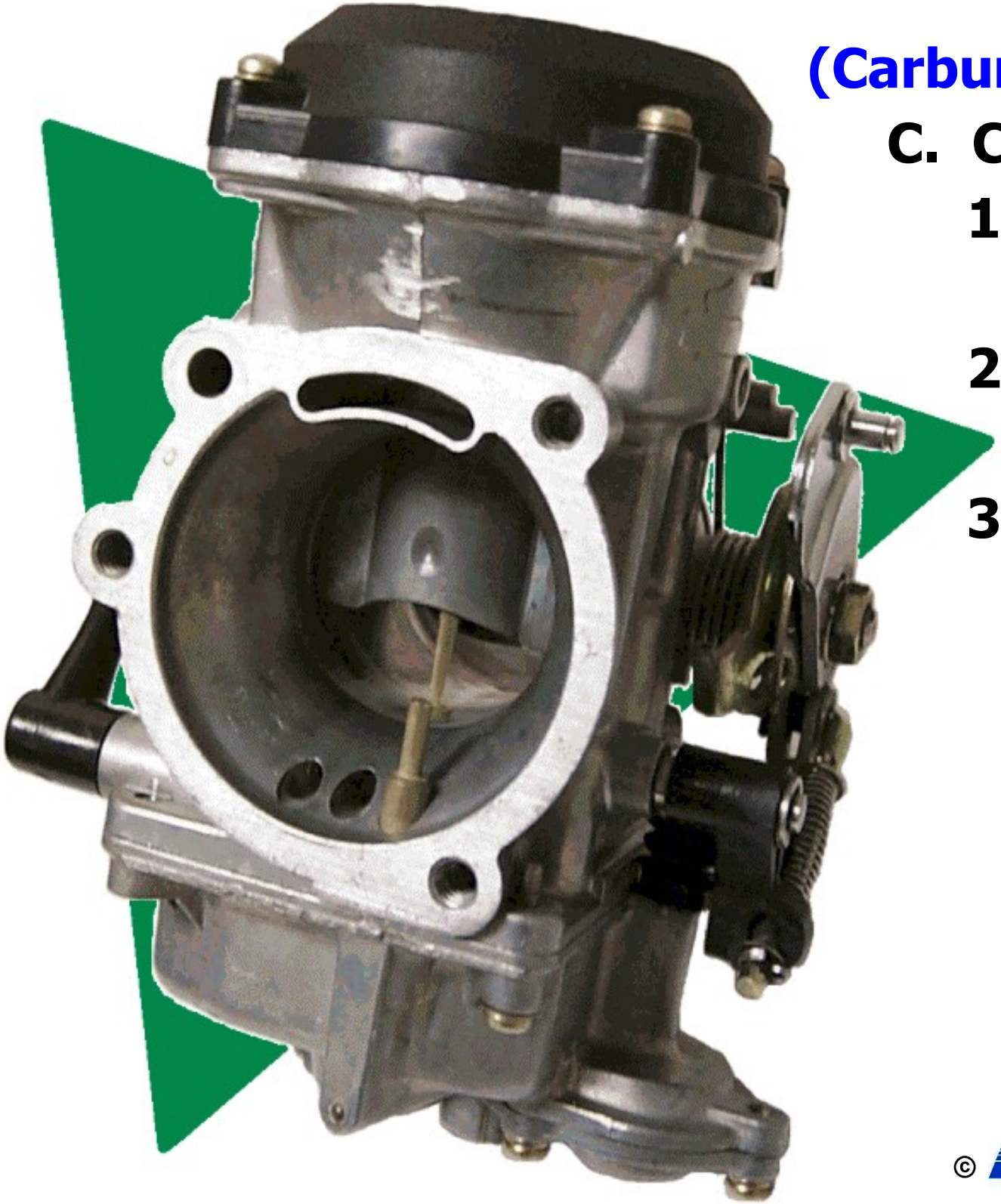
Courtesy Mikuni Corp.

(Circuits, cont.)

e. Main

1) $^{3}/_{4}$-WOT

2) Main jet final fuel flow restriction



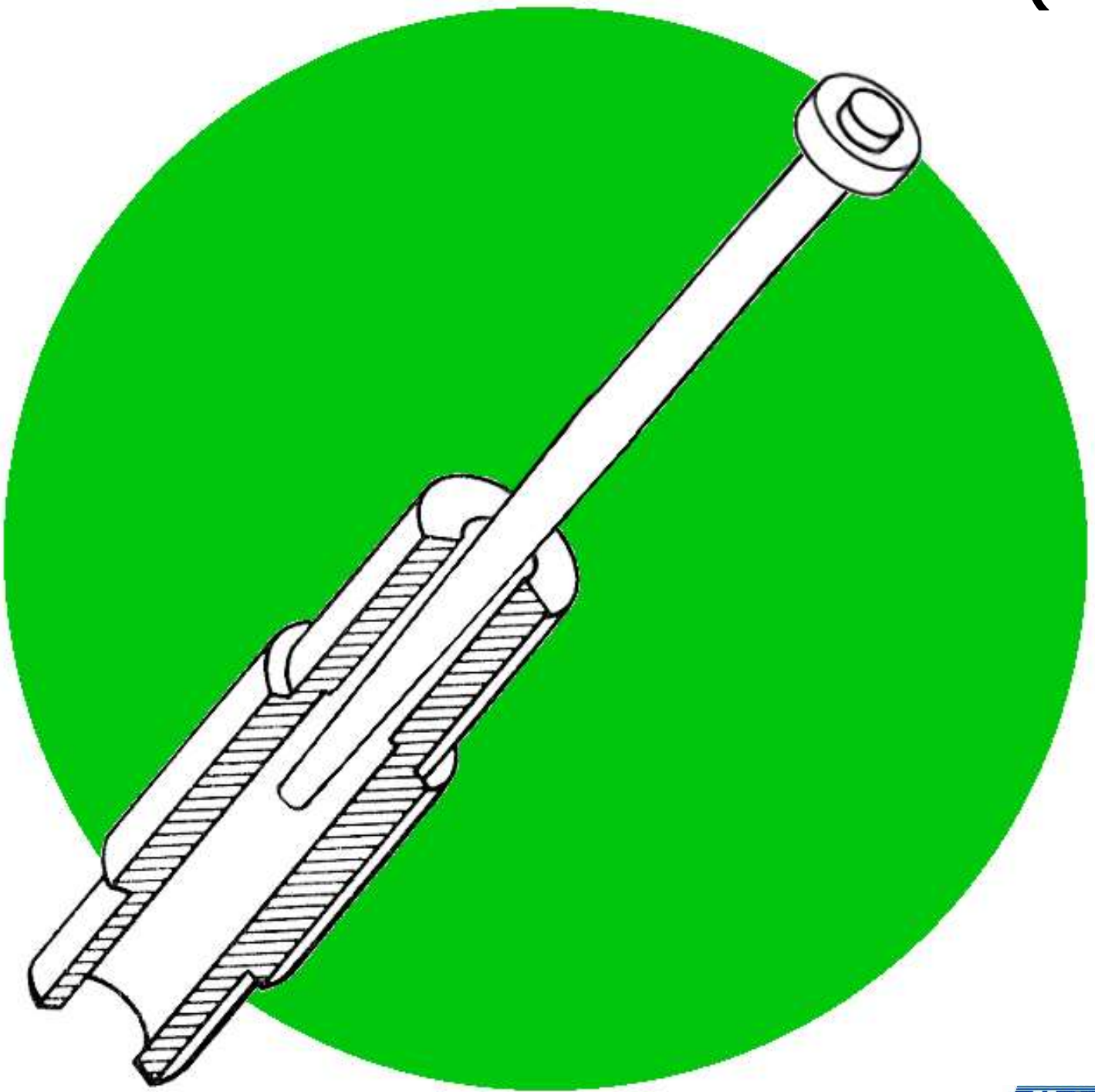
(Carburetor Types, cont.)

C. Constant velocity
   1. Butterfly throttle and slide venturi
   2. Butterfly throttle controls airflow
   3. Needle jet and jet needle just like mechanical slide carburetor

(Needle jet, cont.)

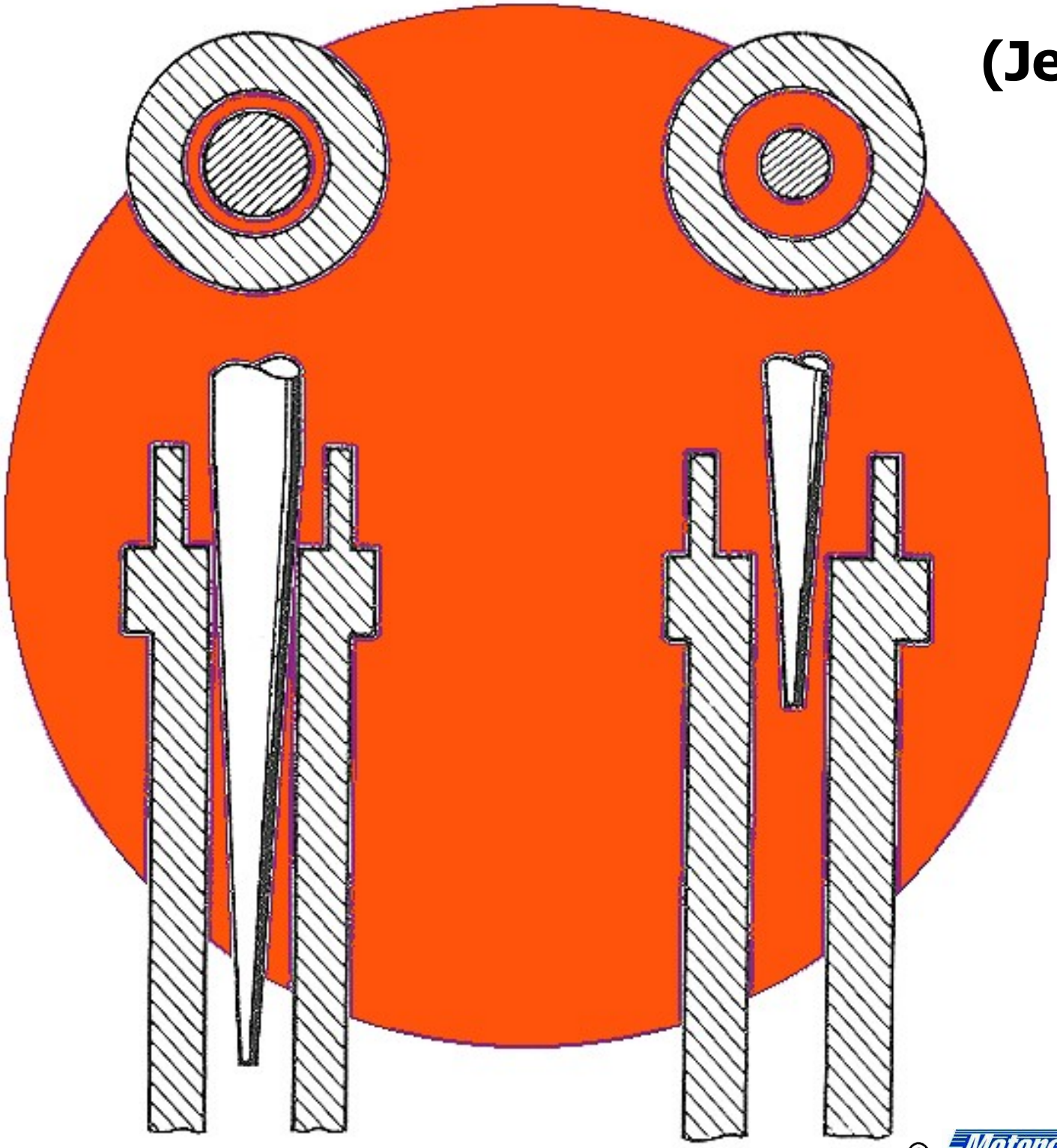
a. Three types
   1) Primary
      a) Hooded
      b) Often just one hole
      c) 2-strokes, racing carbs
   2) Bleed
      a) No hood
      b) Many holes
      c) 4-strokes
   3) Primary/bleed (combined attributes)

Shown with main jet attached



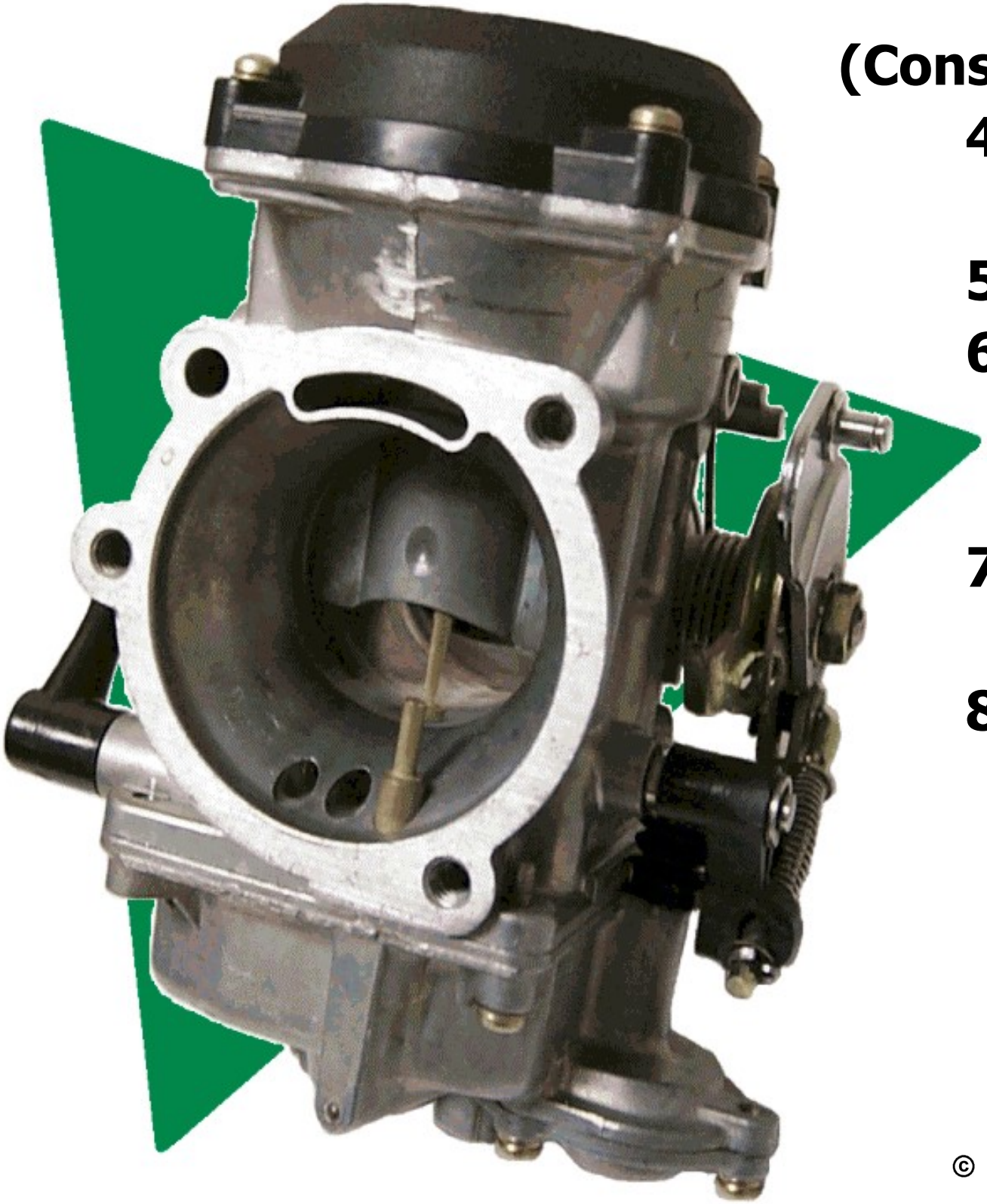
(Jet needle, cont.)

b. Flow area increases as needle is raised
c. Needle is not adjustable on emissions carburetors
d. Needle often has less of a taper on emissions carburetors



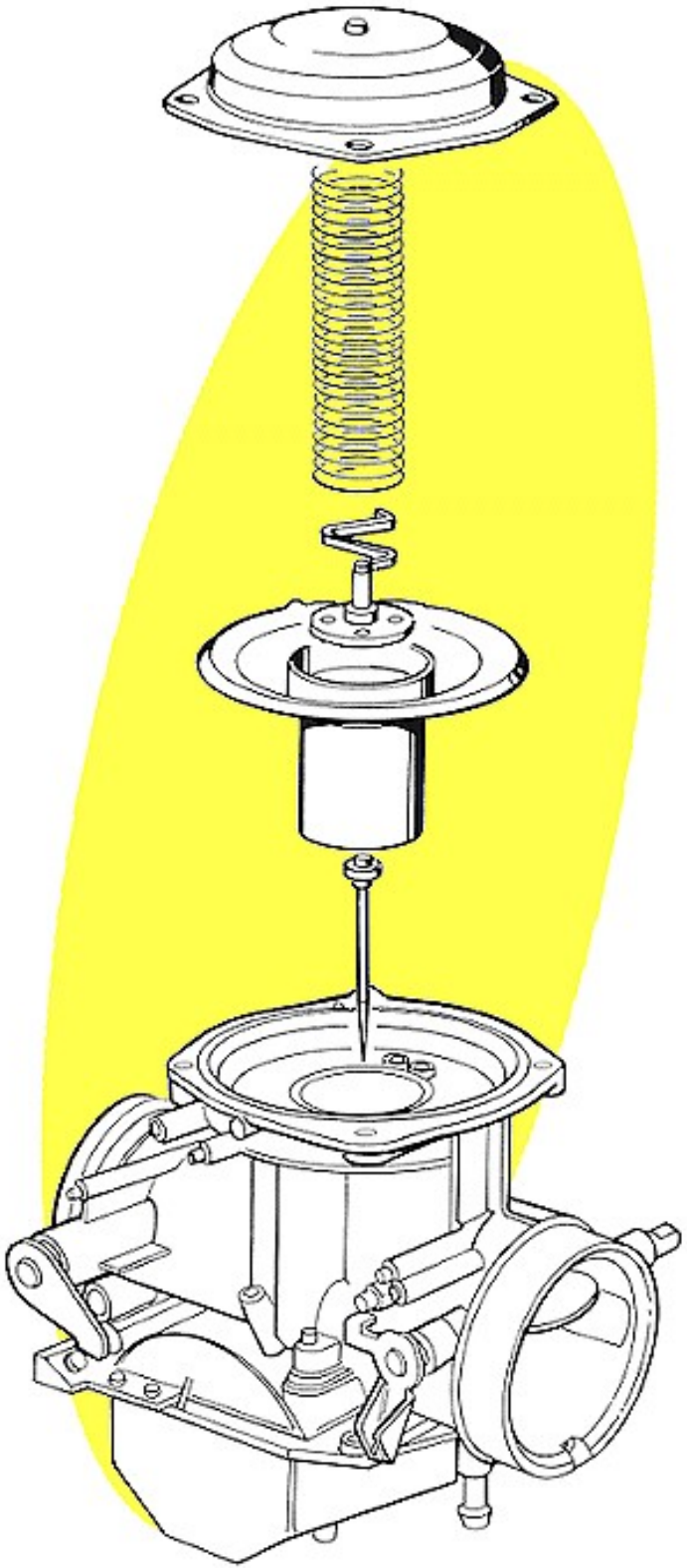
(Jet needle, cont.)

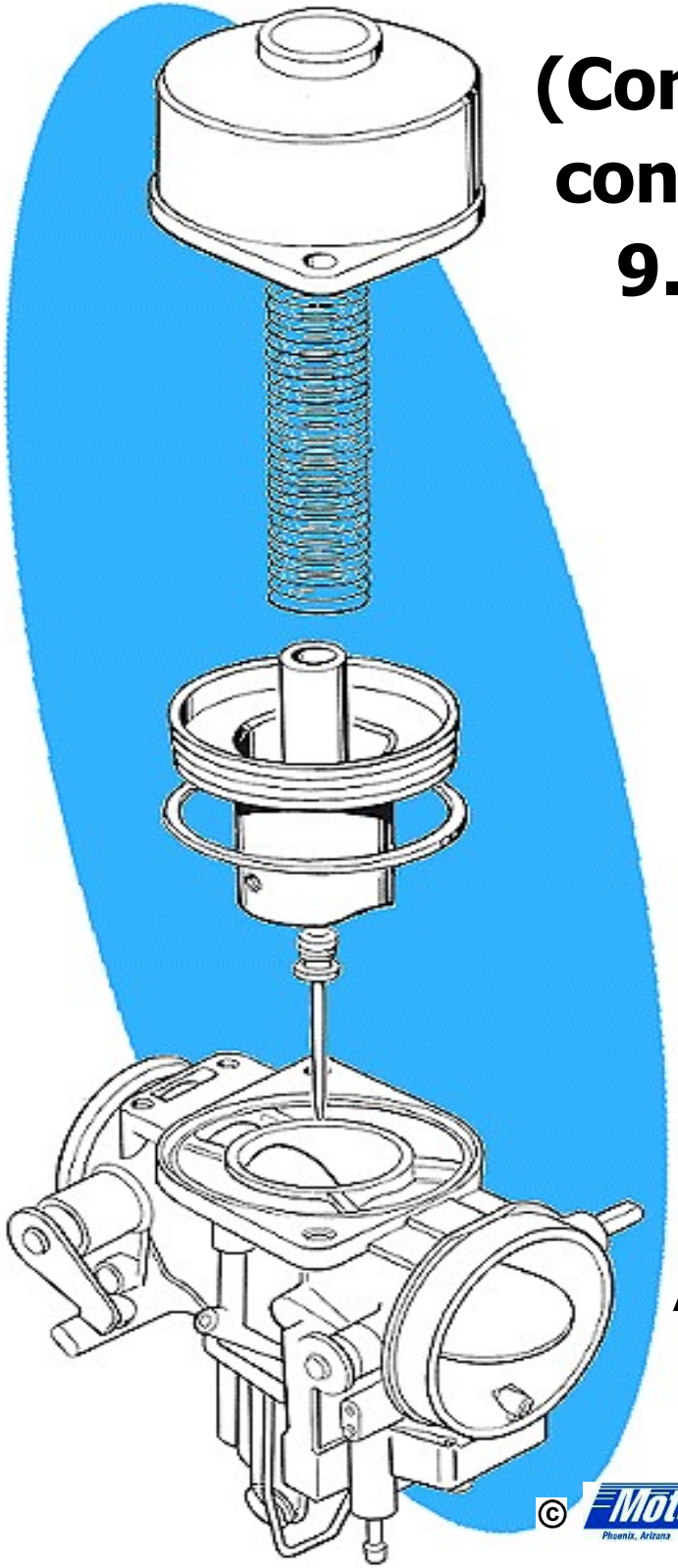
e. Flow area increases as needle is raised further



(Constant velocity, cont.)

4. 3 circuits (plus transfer)
5. Transfer ports
6. 2 air bleeds (needle jet and main share one)
7. Fuel type idle mixture screw
8. Often emissions-spec'd

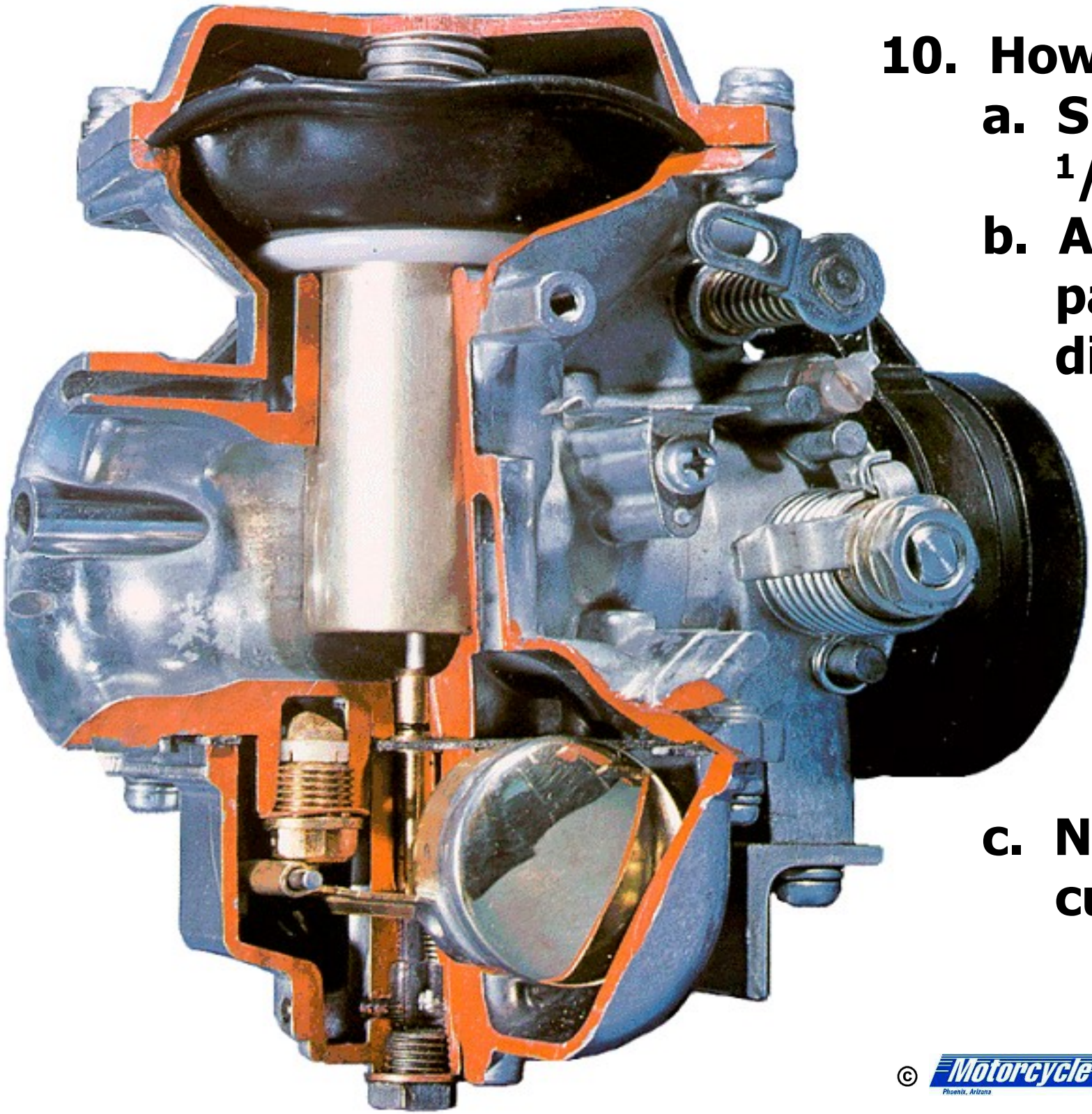




(Constant velocity, cont.)

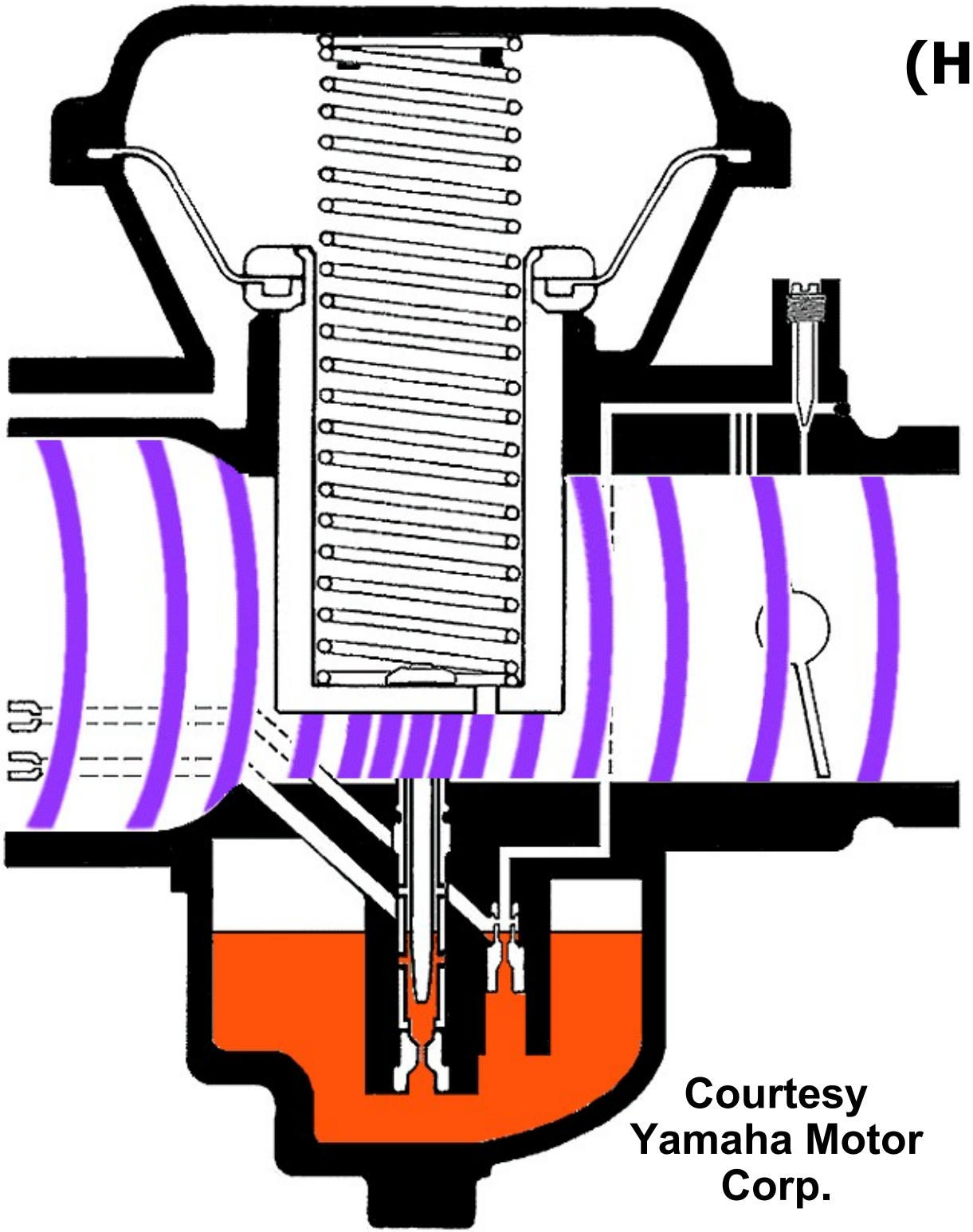
9. Two types
   a. Rubber diaphragm
   b. Metal piston

Courtesy
American Honda
Motor Co.



10. How it works
    a. Slide is already $^1/_4$ up at rest
    b. Atmospheric passage under diaphragm

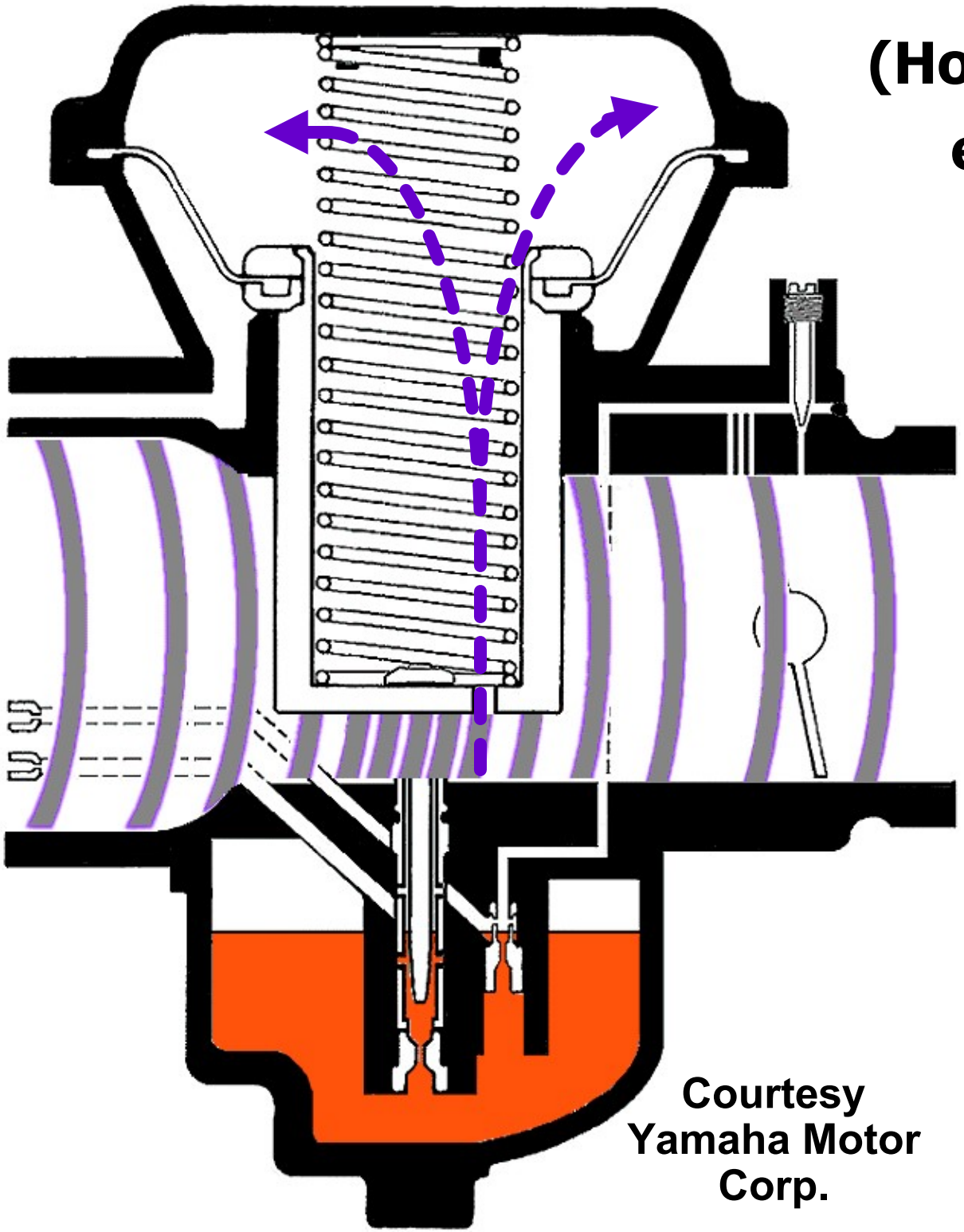
    c. No slide cutaway



Courtesy
Yamaha Motor
Corp.

(How it works, cont.)

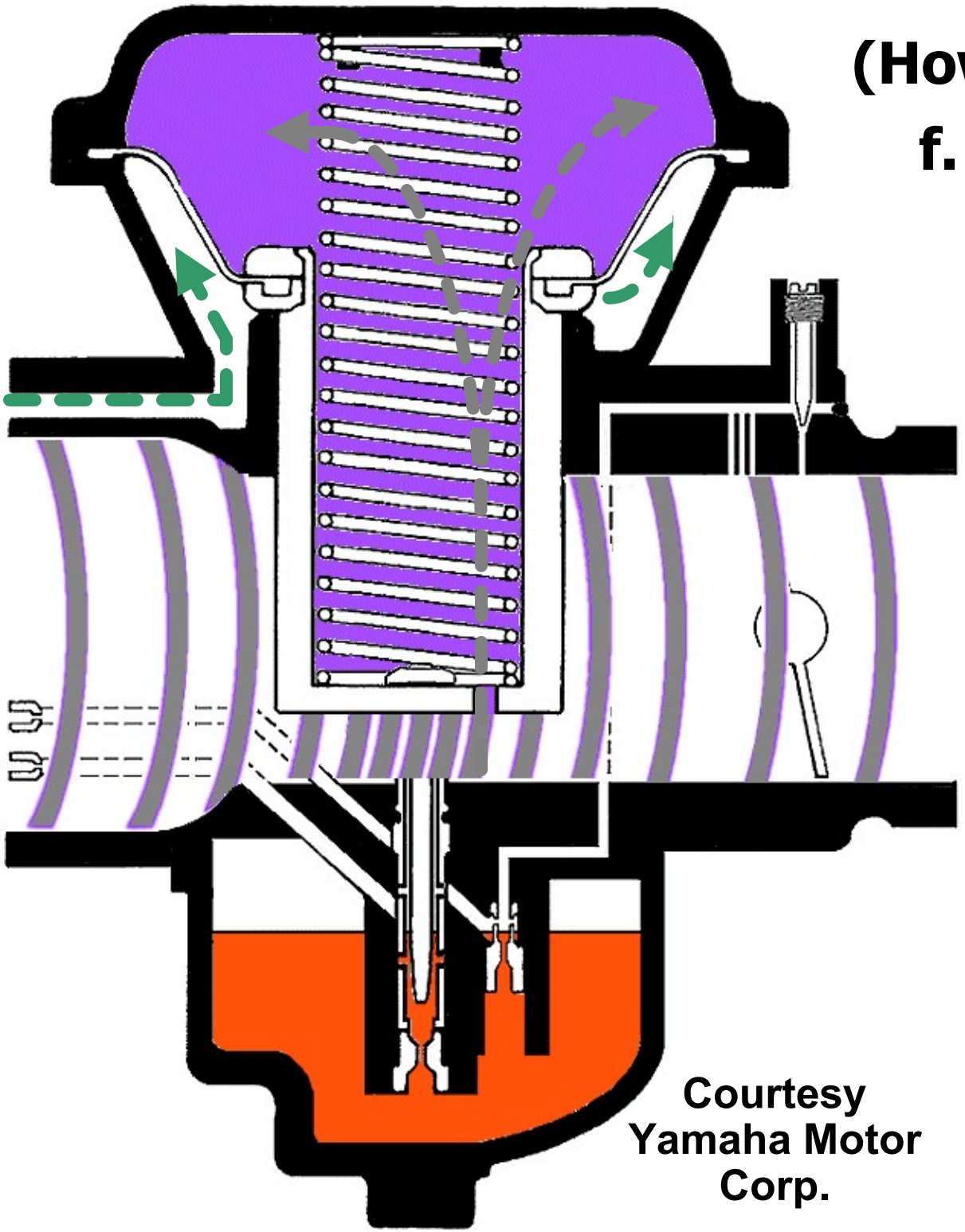
d. Pressure difference under slide created by airflow



Courtesy
Yamaha Motor
Corp.

(How it works, cont.)

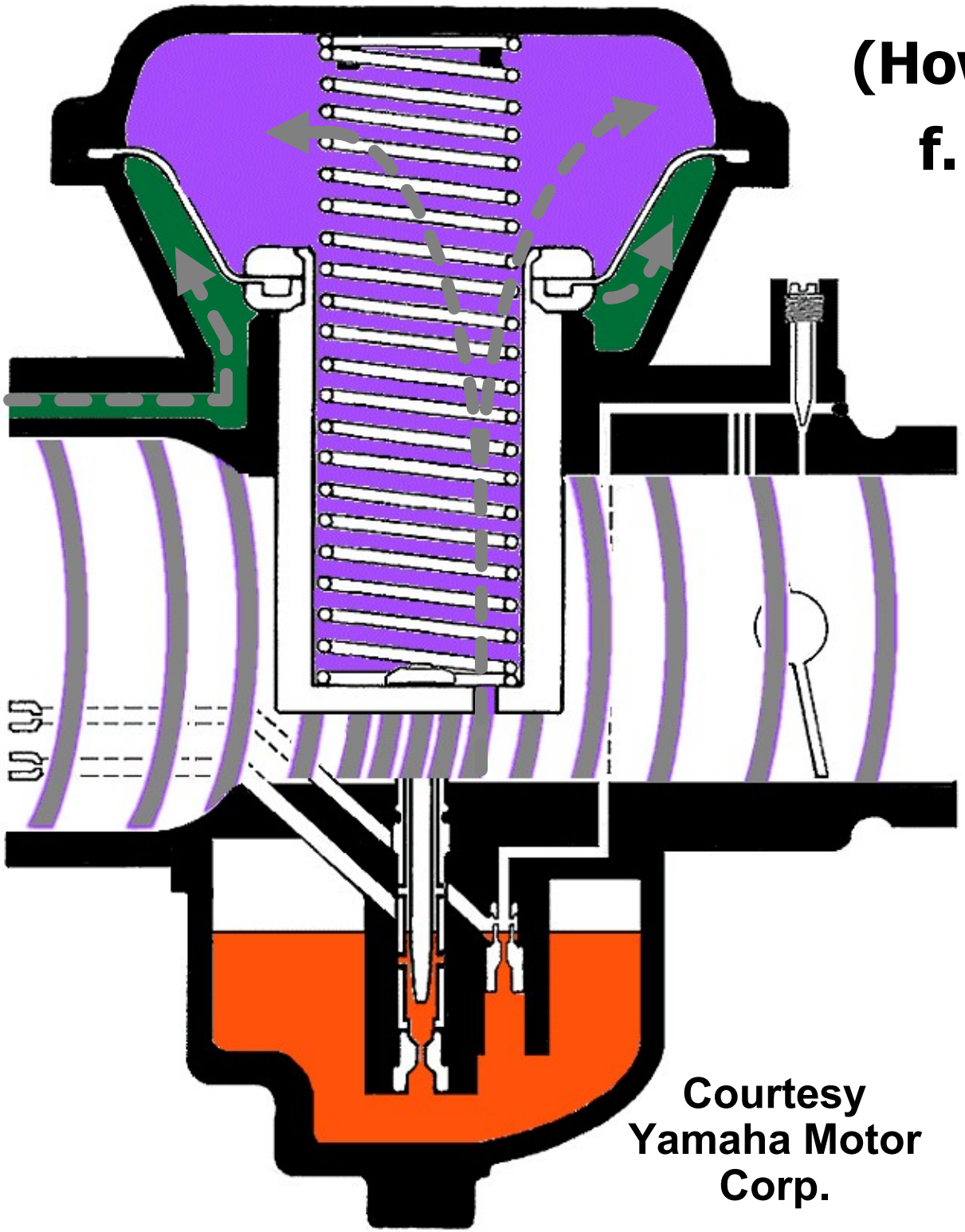
e. This pressure difference sneaks through the hole in the bottom of slide to affect the area above the dia-phragm



Courtesy
Yamaha Motor
Corp.

(How it works, cont.)

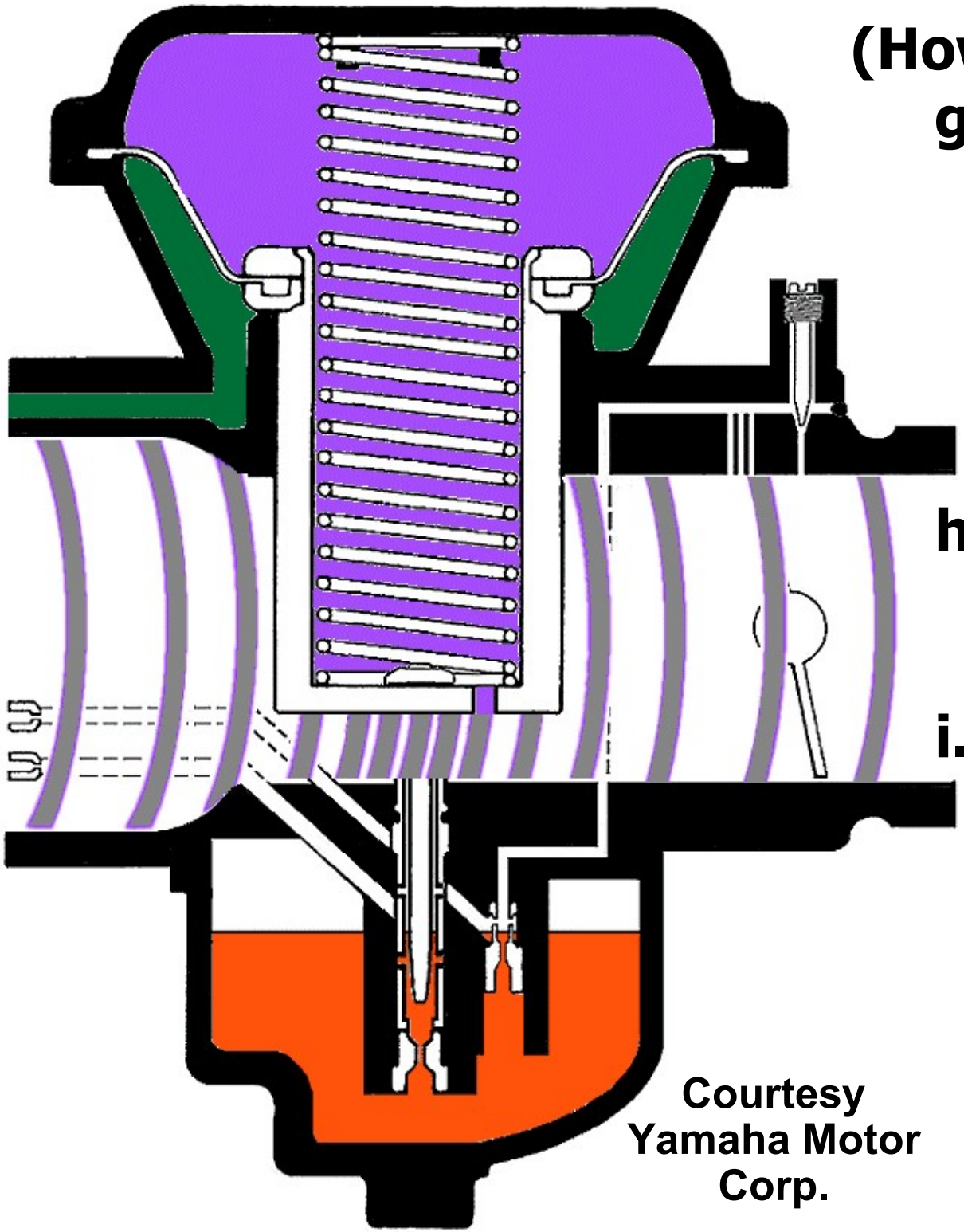
f. Meanwhile, the area below the diaphragm is vented to atmosphere (which is higher pressure)



Courtesy
Yamaha Motor
Corp.

(How it works, cont.)

f. Meanwhile, the area below the diaphragm is vented to atmosphere (which is higher pressure)



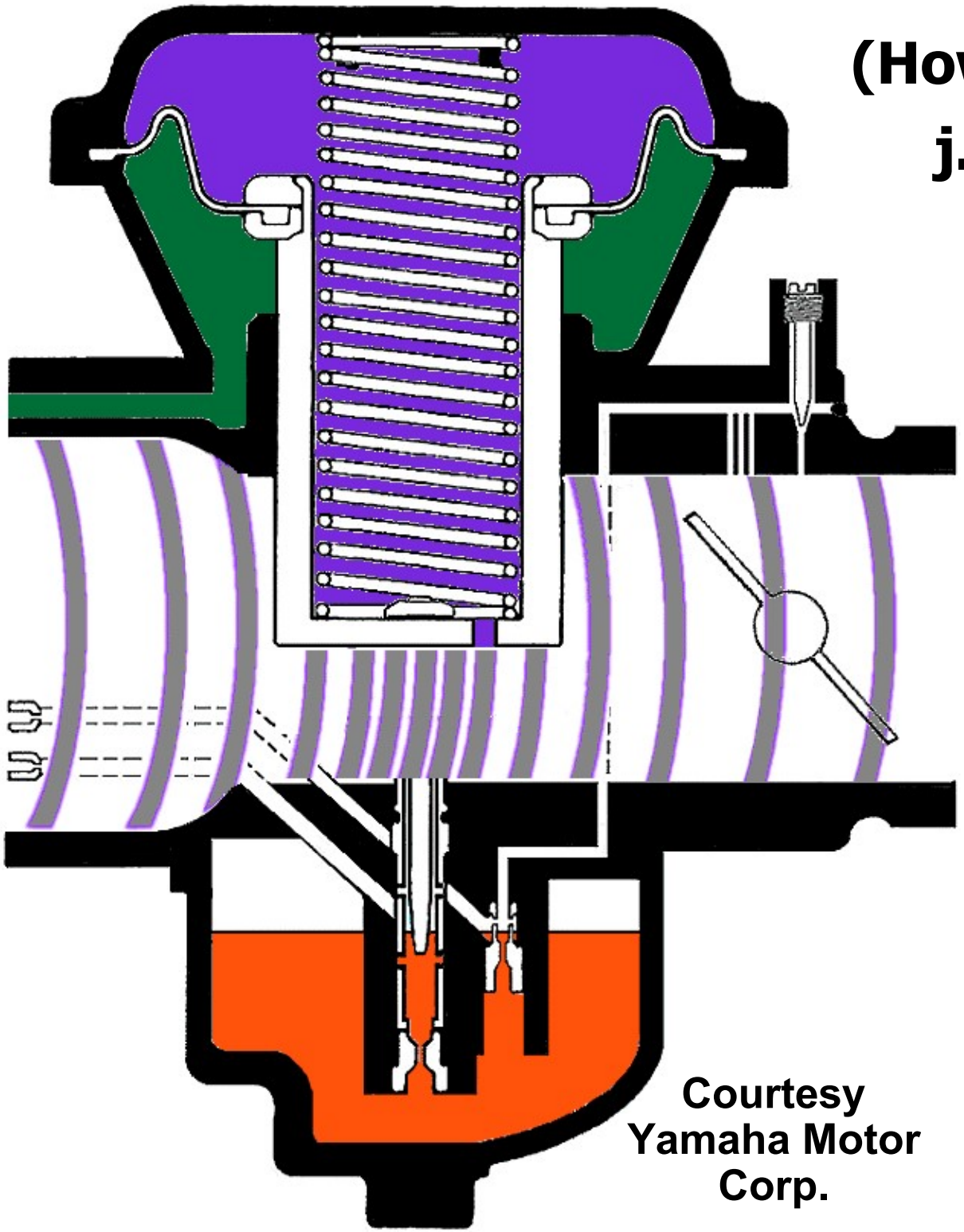
Courtesy
Yamaha Motor
Corp.

(How it works, cont.)

g. The result is a difference in pressure between the over-diaphragm and under-diaphragm areas

h. This pressure difference tries to lift the slide

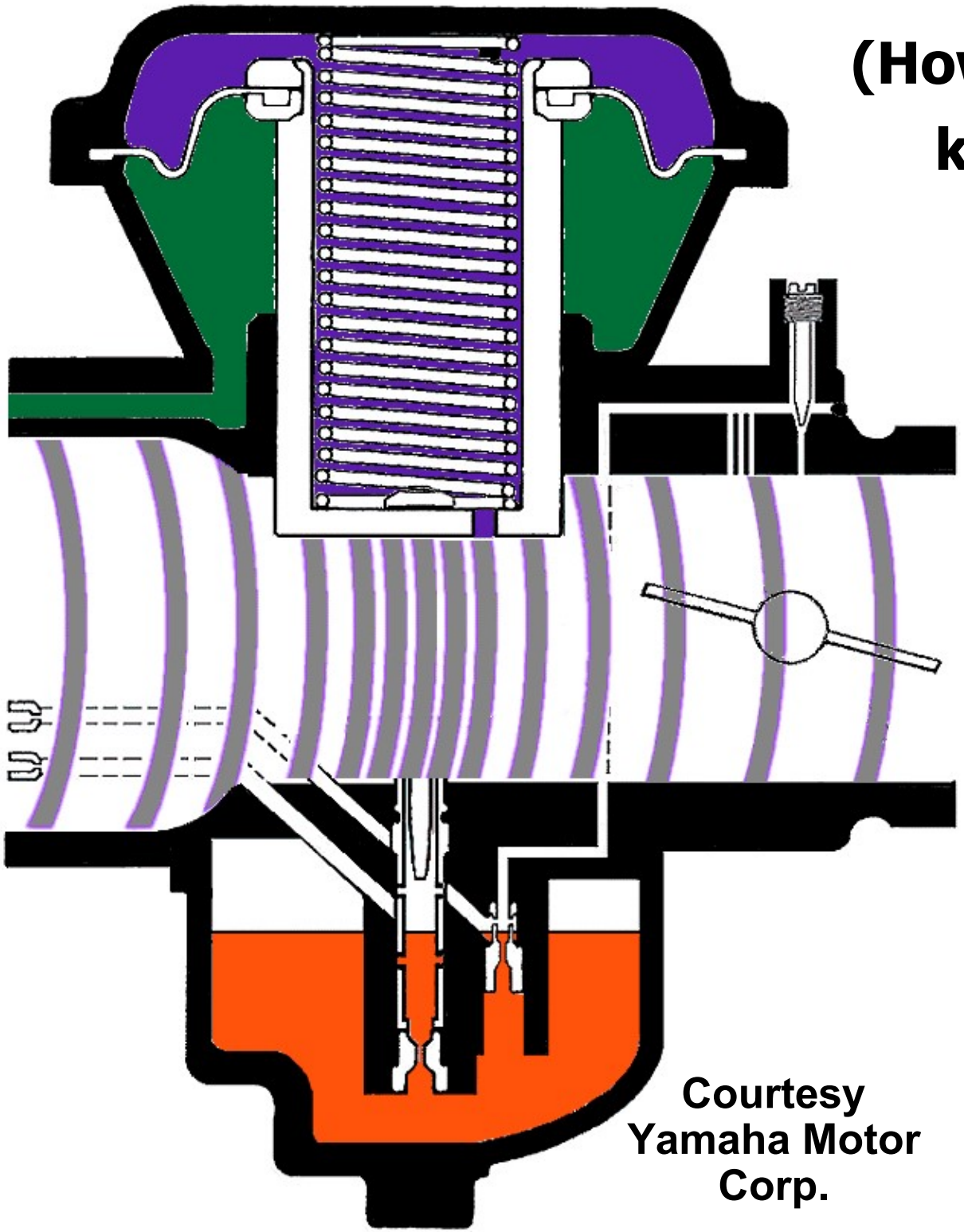
i. At first the pressure difference isn't strong enough to lift the slide



Courtesy
Yamaha Motor
Corp.

(How it works, cont.)

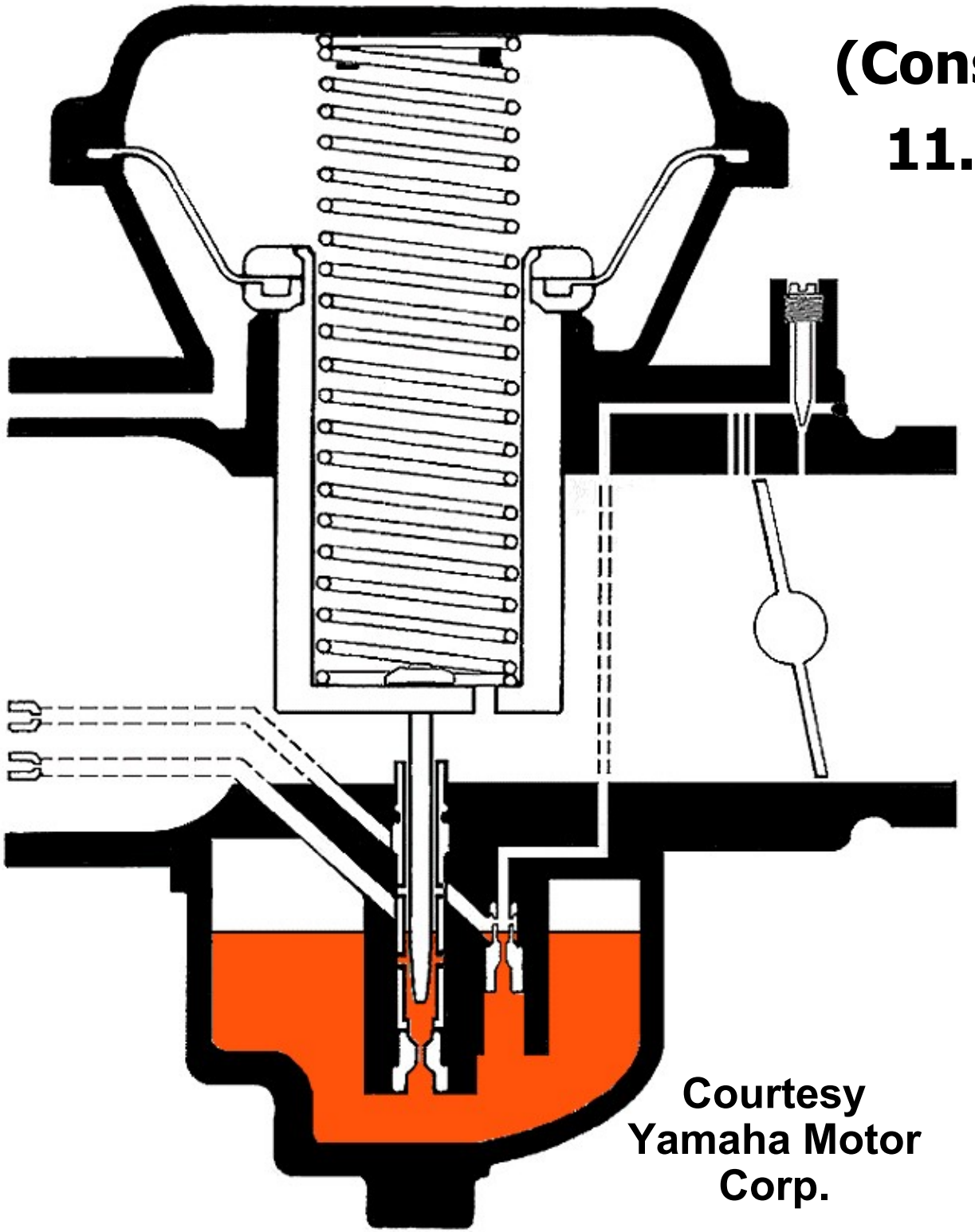
j. But once the throttle is open far enough, the airflow increases until the pressure difference becomes high enough to over-come the weight of the slide and the force of the spring, and the slide begins to lift



Courtesy
Yamaha Motor
Corp.

(How it works, cont.)

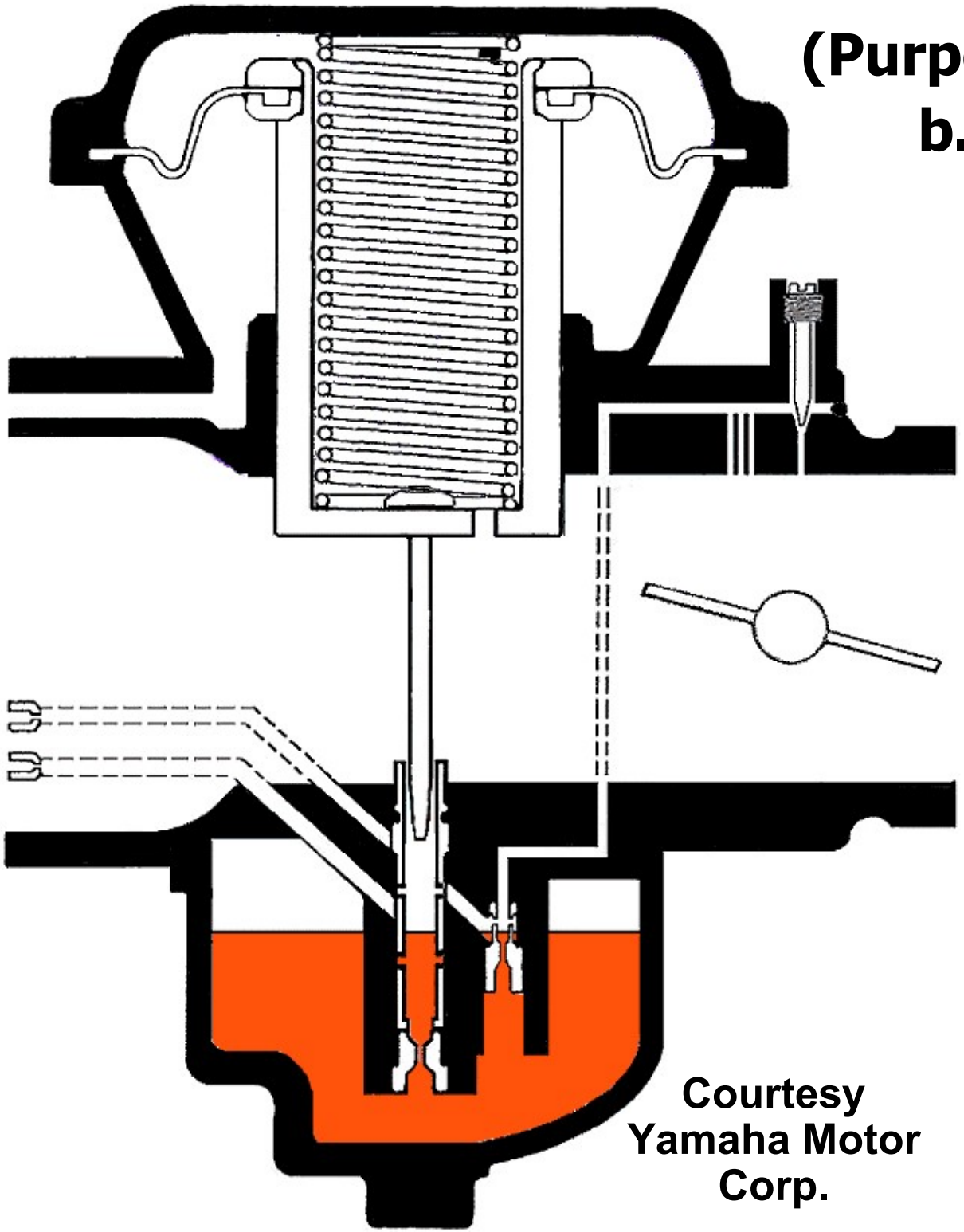
k. As the throttle is opened further, the increased airflow results in a greater pressure difference between the over-diaphragm and the under-diaphragm areas, and the slide lifts even higher



Courtesy
Yamaha Motor
Corp.

(Constant velocity, cont.)

11. **Purposes of the CV**
    a. **Venturi size controlled by the needs of the <u>engine</u>, not the whim of the <u>rider</u>**

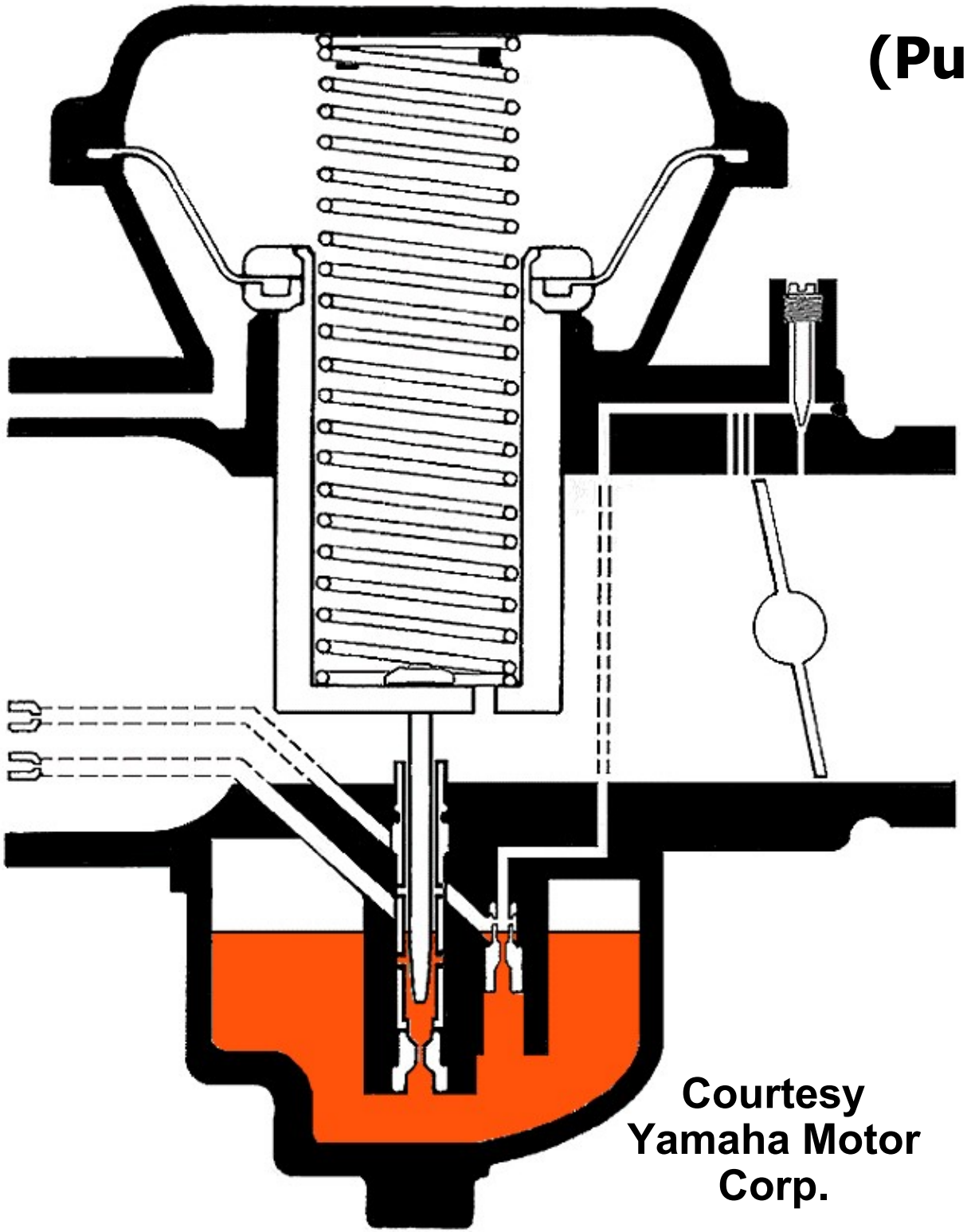


Courtesy
Yamaha Motor
Corp.

(Purpose of the CV, cont.)

b. Constant venturi velocity, for consistent fuel atomization and discharge

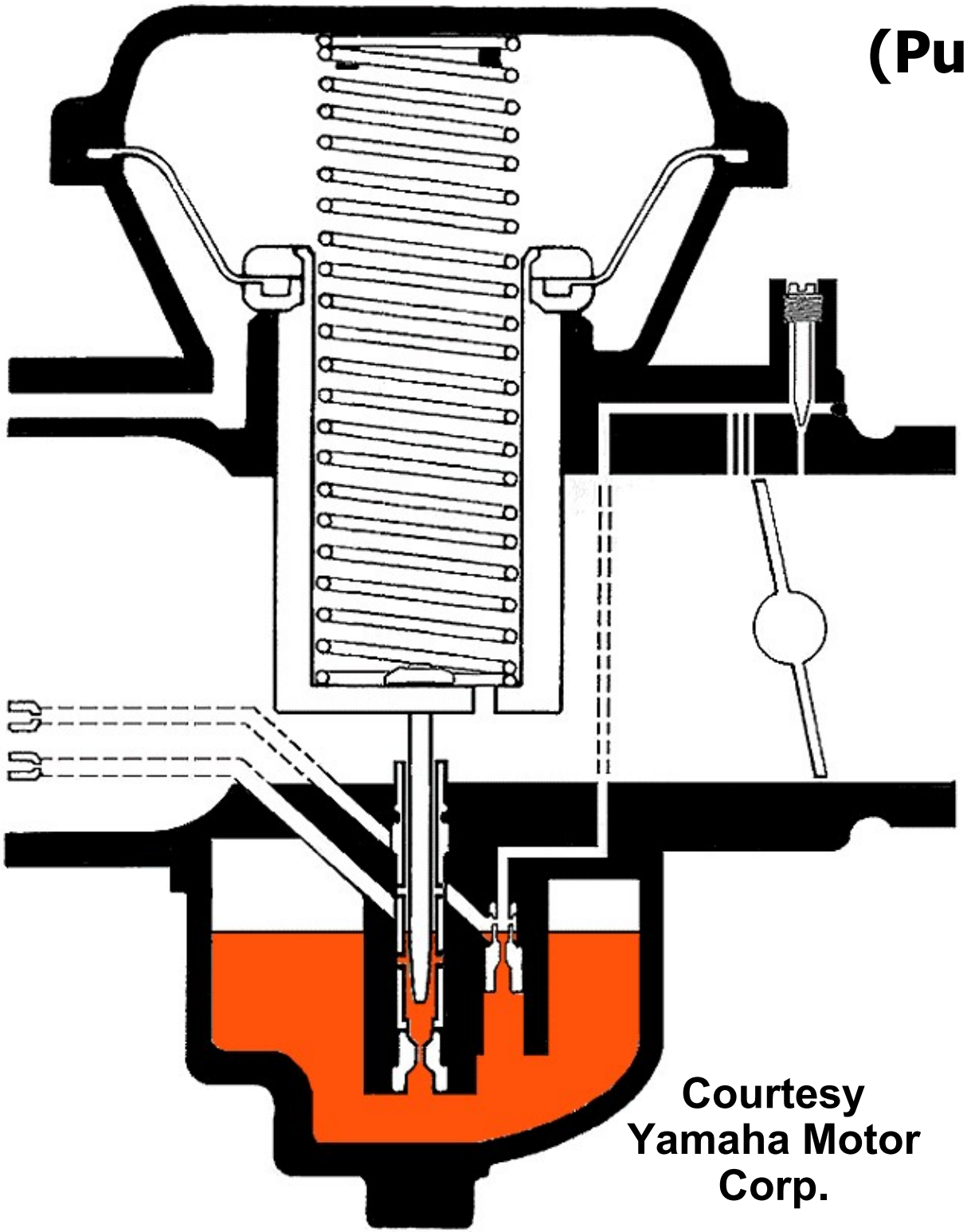
1) When a wider throttle opening increases the venturi velocity, the slide lifts to stabilize the velocity



Courtesy
Yamaha Motor
Corp.

(Purpose of the CV, cont.)

2) When a smaller throttle opening decreases venturi velocity, the slide lowers to stabilize the velocity



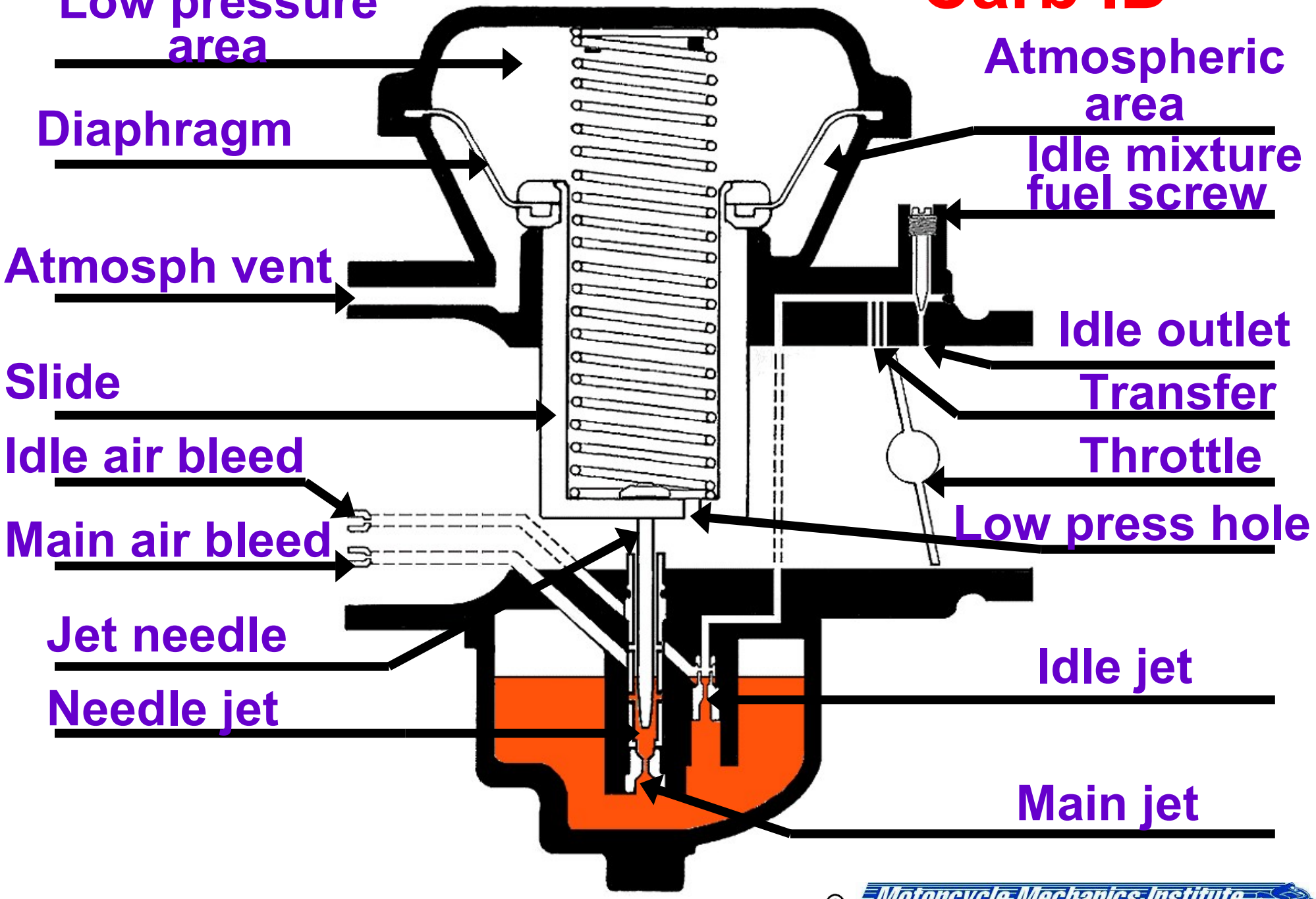
Courtesy
Yamaha Motor
Corp.

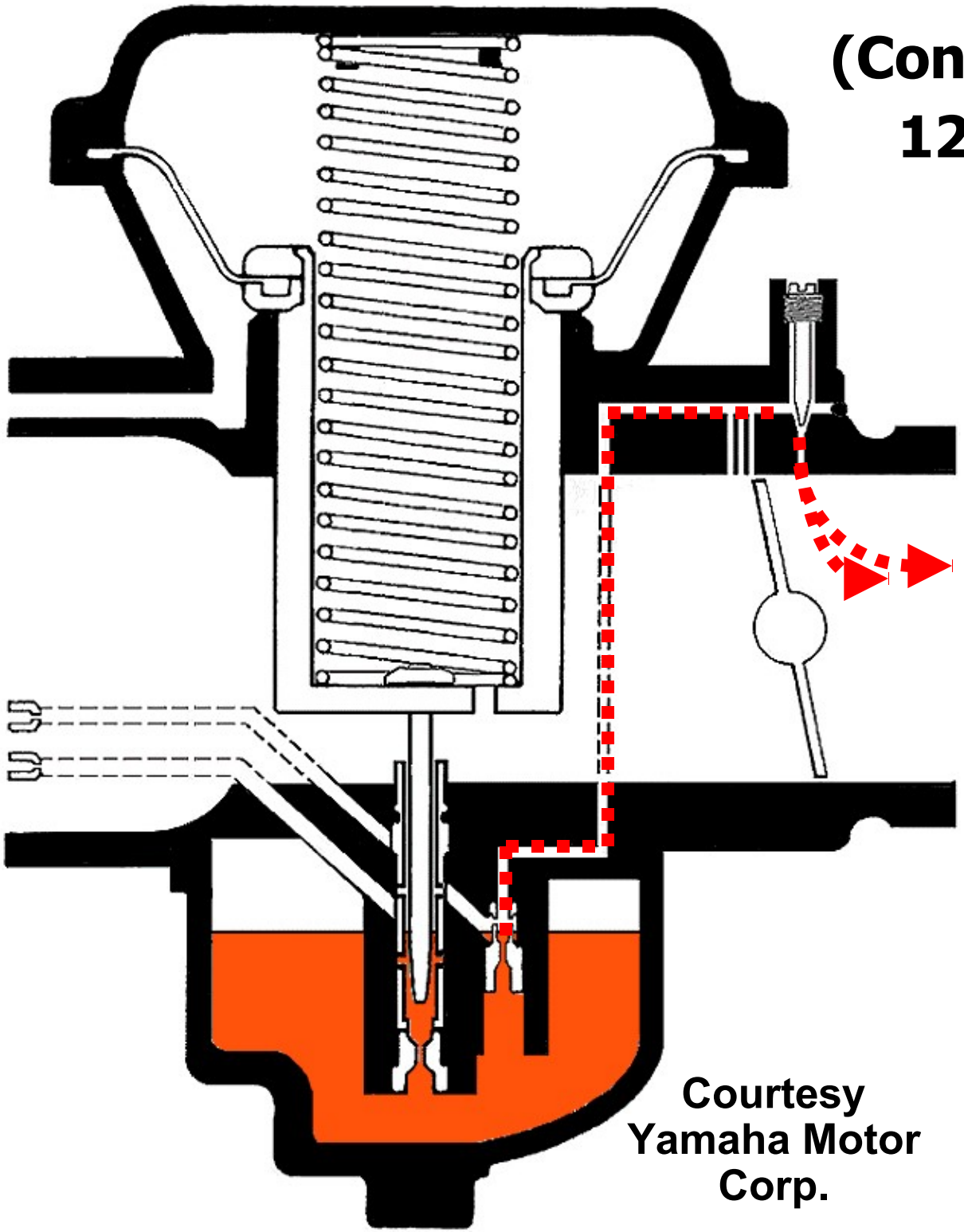
(Purpose of the CV, cont.)

3) The result is nearly constant venturi velocity regardless of throttle opening
4) This makes fuel delivery more precise, better atomized, and more instantaneous (similar to fuel injection)

(Constant velocity, cont.)

Carb ID



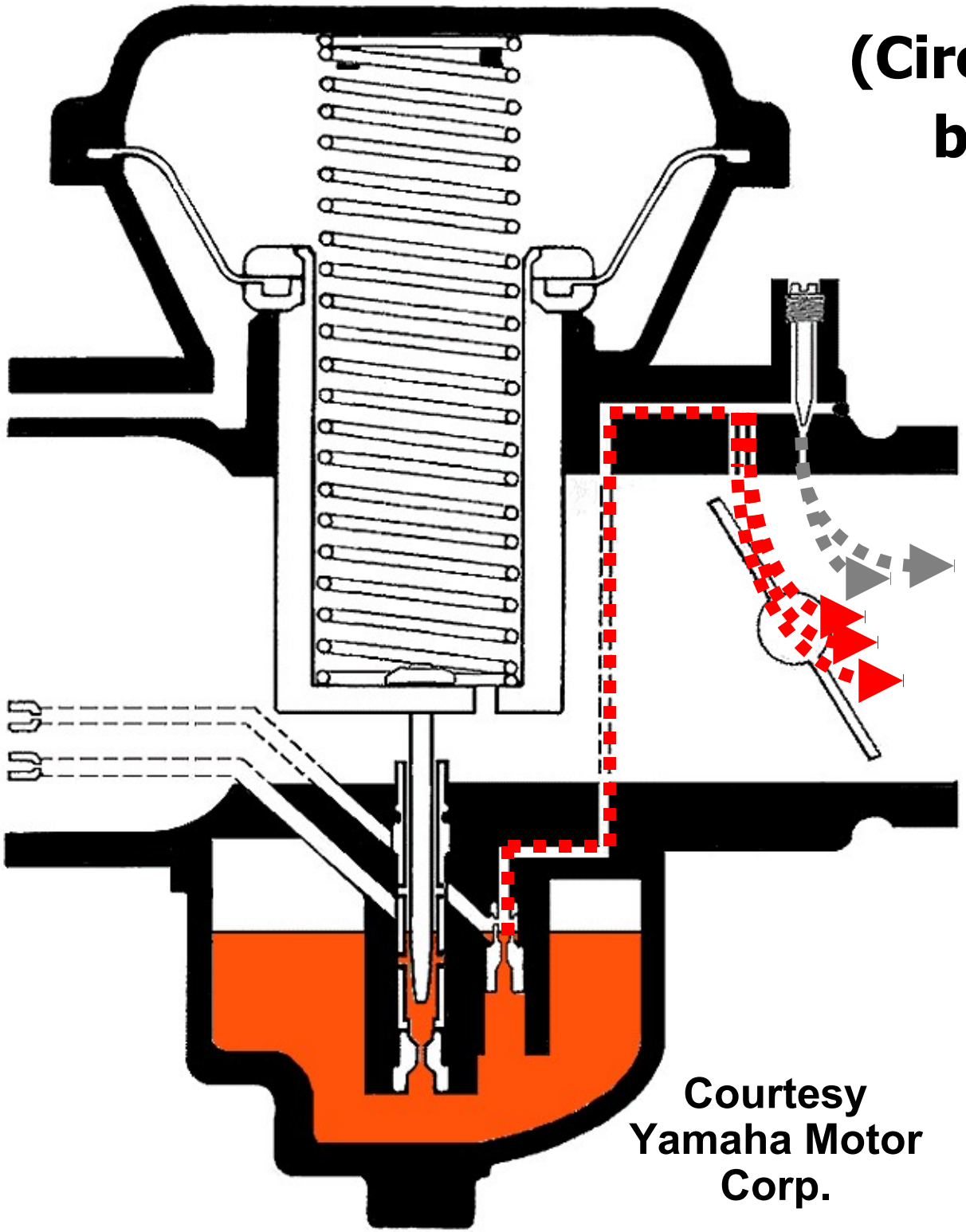


Courtesy
Yamaha Motor
Corp.

(Constant velocity, cont.)

12. Circuits
    a. Idle
        1) 0-$^{1}/_{4}$ throttle
        2) On engine side of the throttle
        3) Always on

2-Jet CV



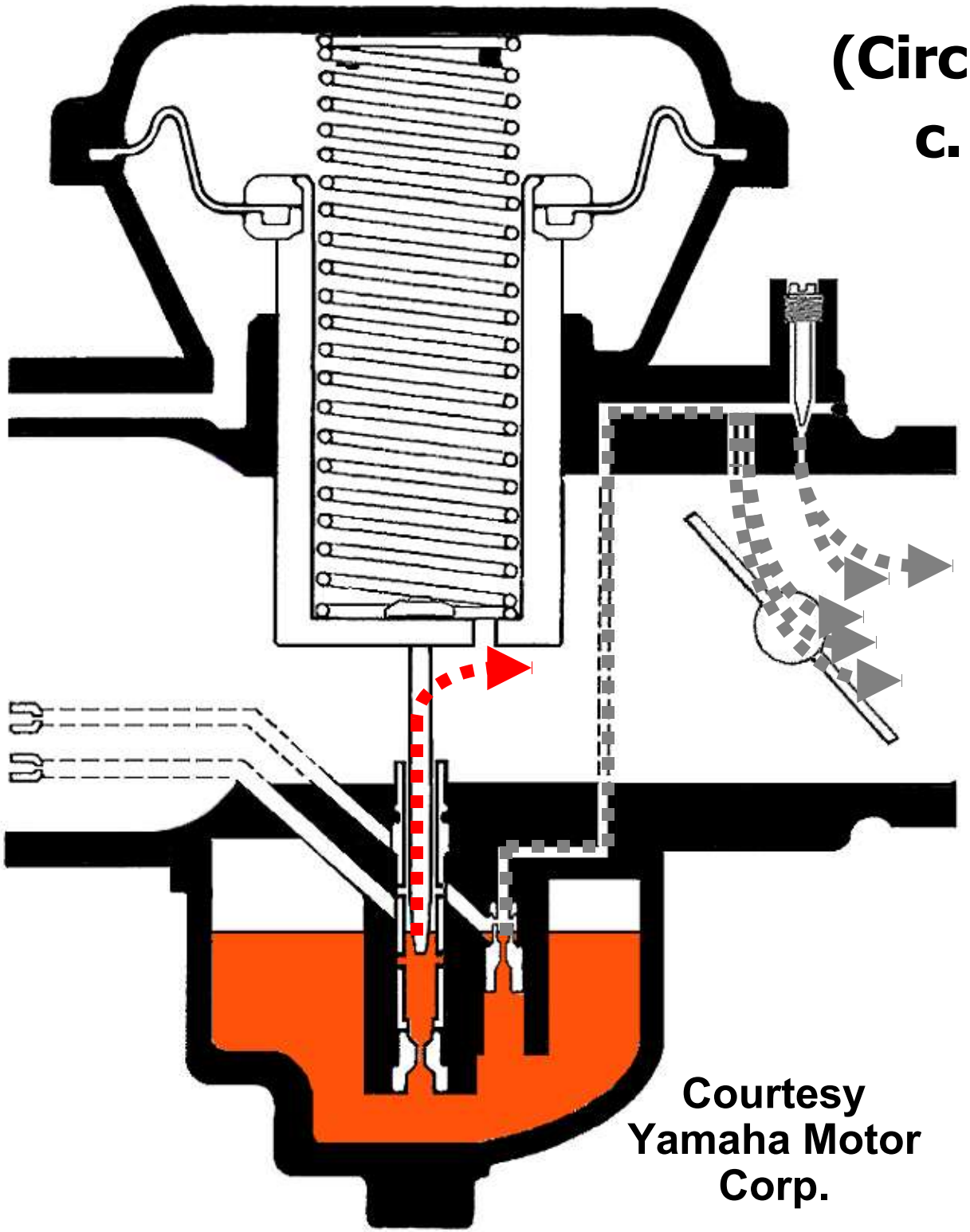
(Circuits, continued)

b. Transfer (bypass)

1) Just off idle
2) Transition from idle to needle
3) Uncovered by throttle butterfly

2-Jet CV

Courtesy Yamaha Motor Corp.



(Circuits, continued.)

c. Needle jet

1) $^{1}/_{4}$-$^{3}/_{4}$ throttle

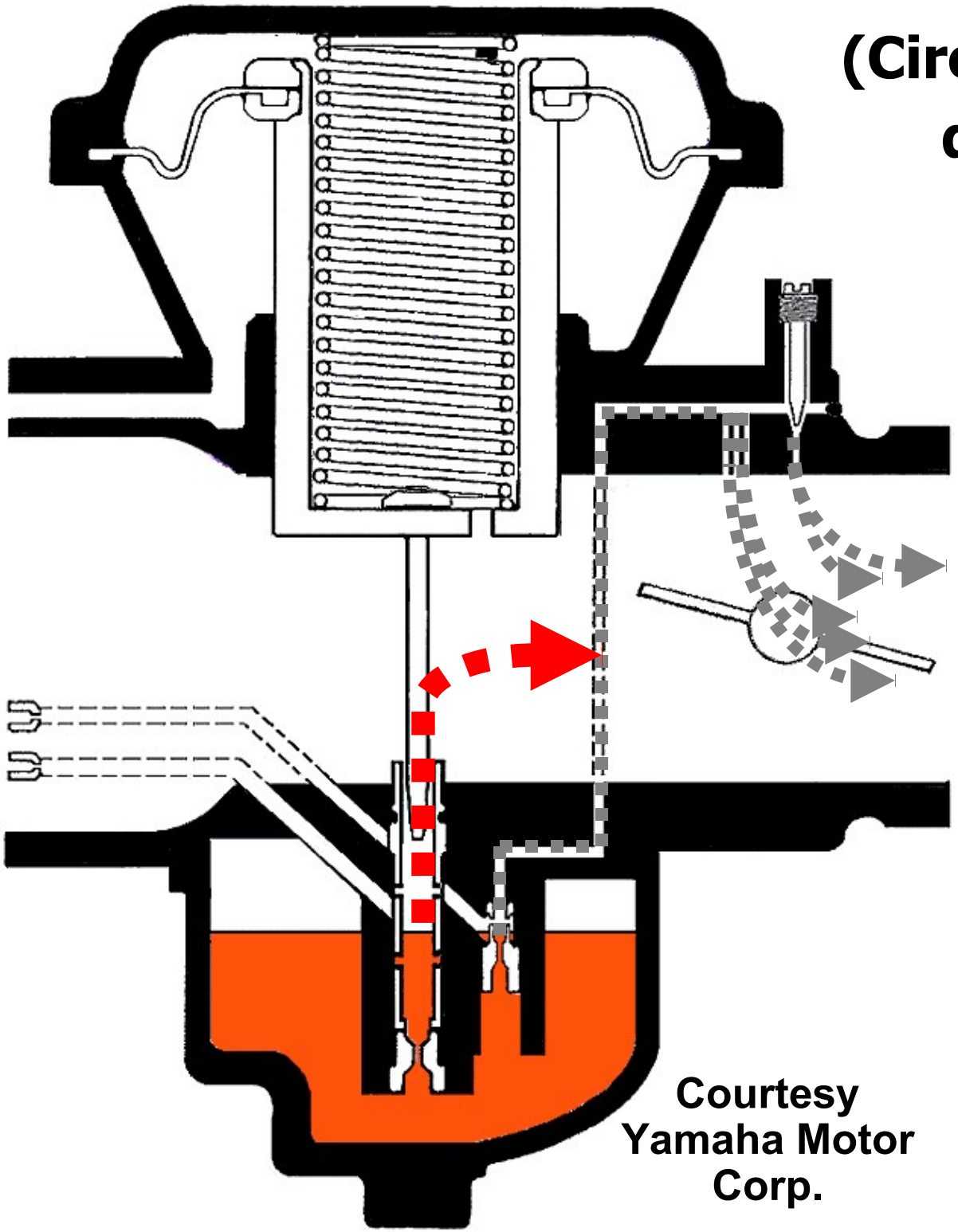
a) Widest range

b) Most ridden

2) Considered the "midrange" circuit

2-Jet CV

Courtesy Yamaha Motor Corp.



(Circuits, continued.)

d. Main

1) $^{3}/_{4}$-WOT

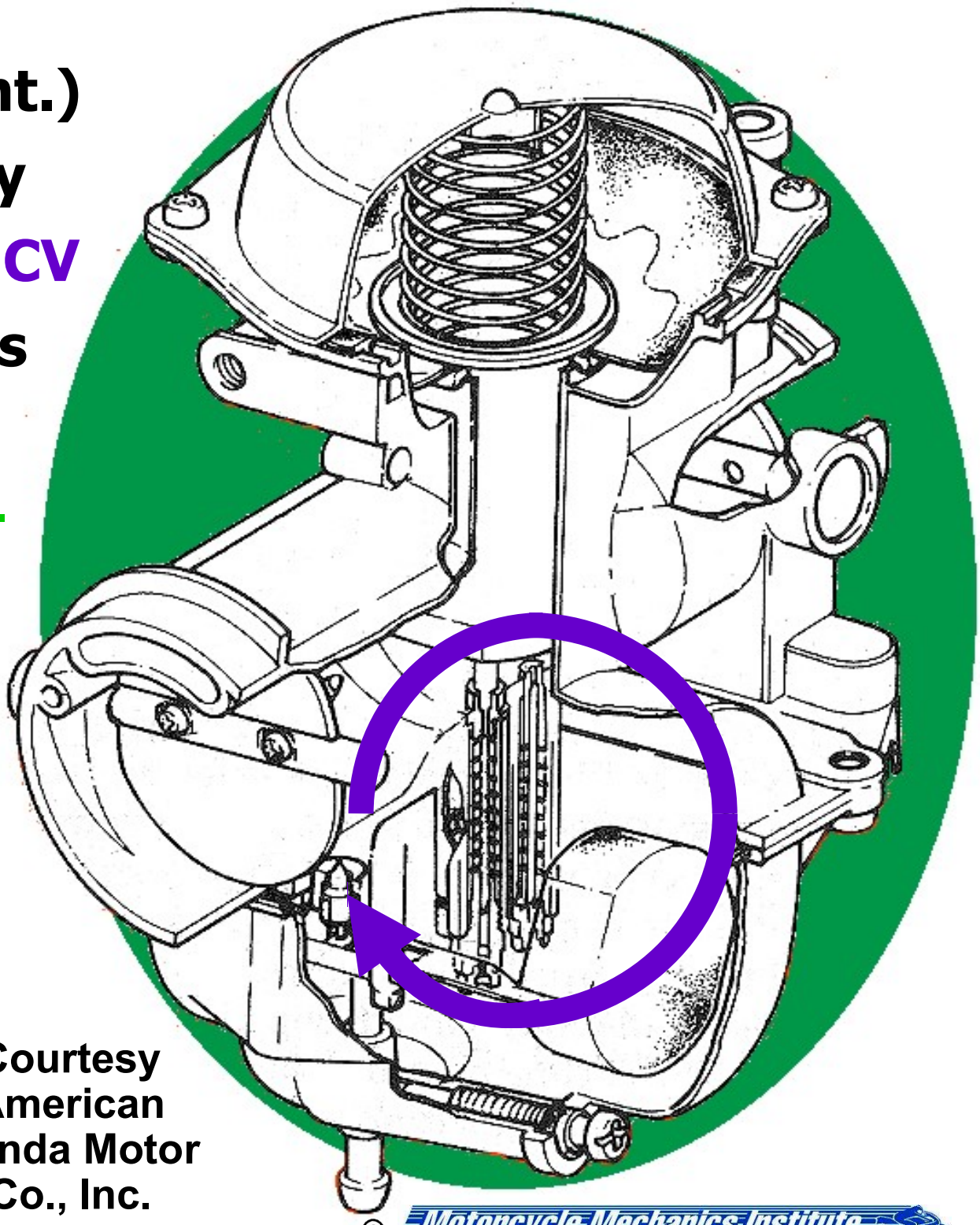
2) Main jet is final fuel restriction

2-Jet CV

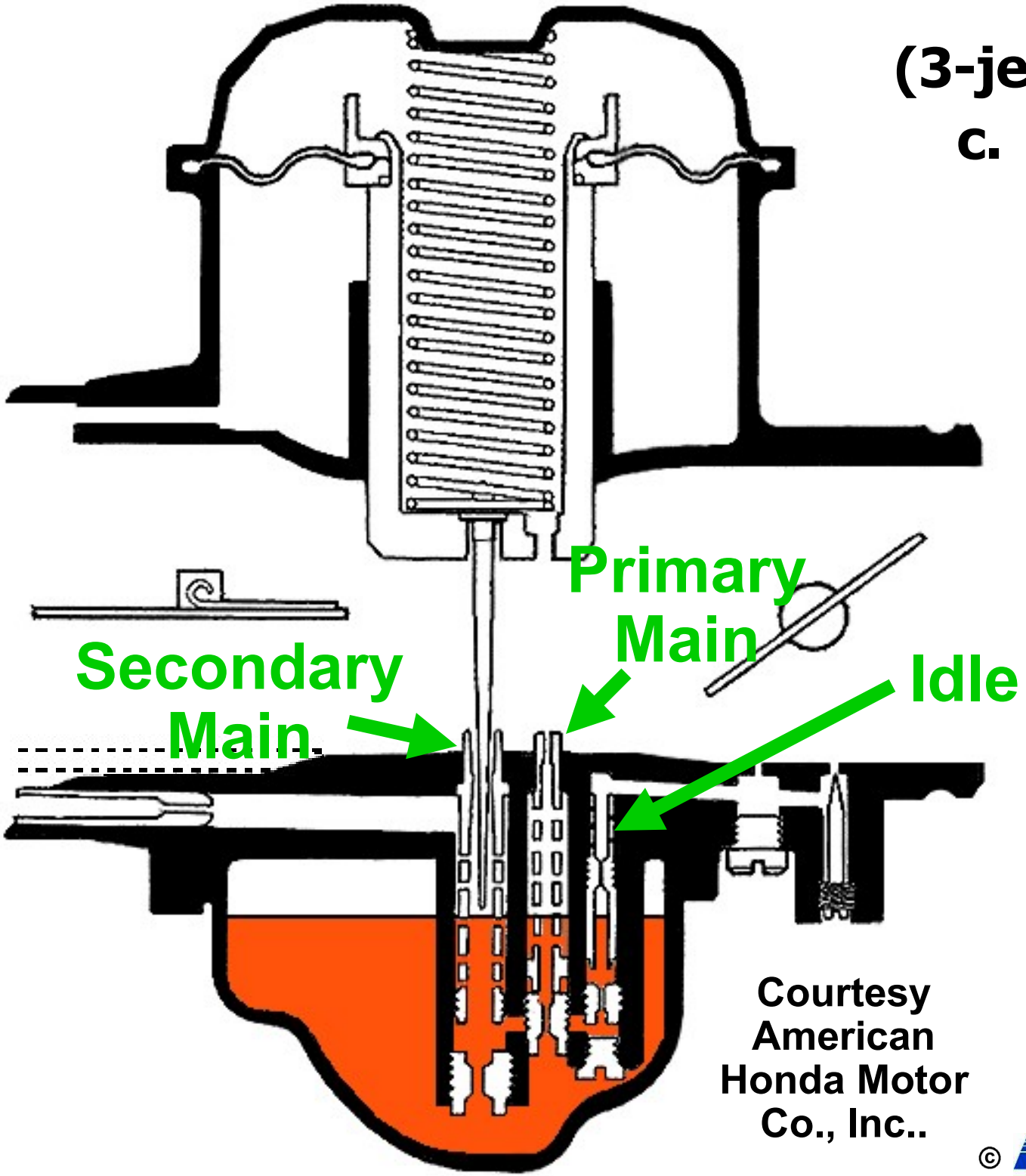
Courtesy Yamaha Motor Corp.

(Constant velocity, cont.)

13. Constant velocity variation: 3-jet CV
    a. Two main jets
    b. Benefit is superior mid-range fuel delivery



Courtesy American Honda Motor Co., Inc.



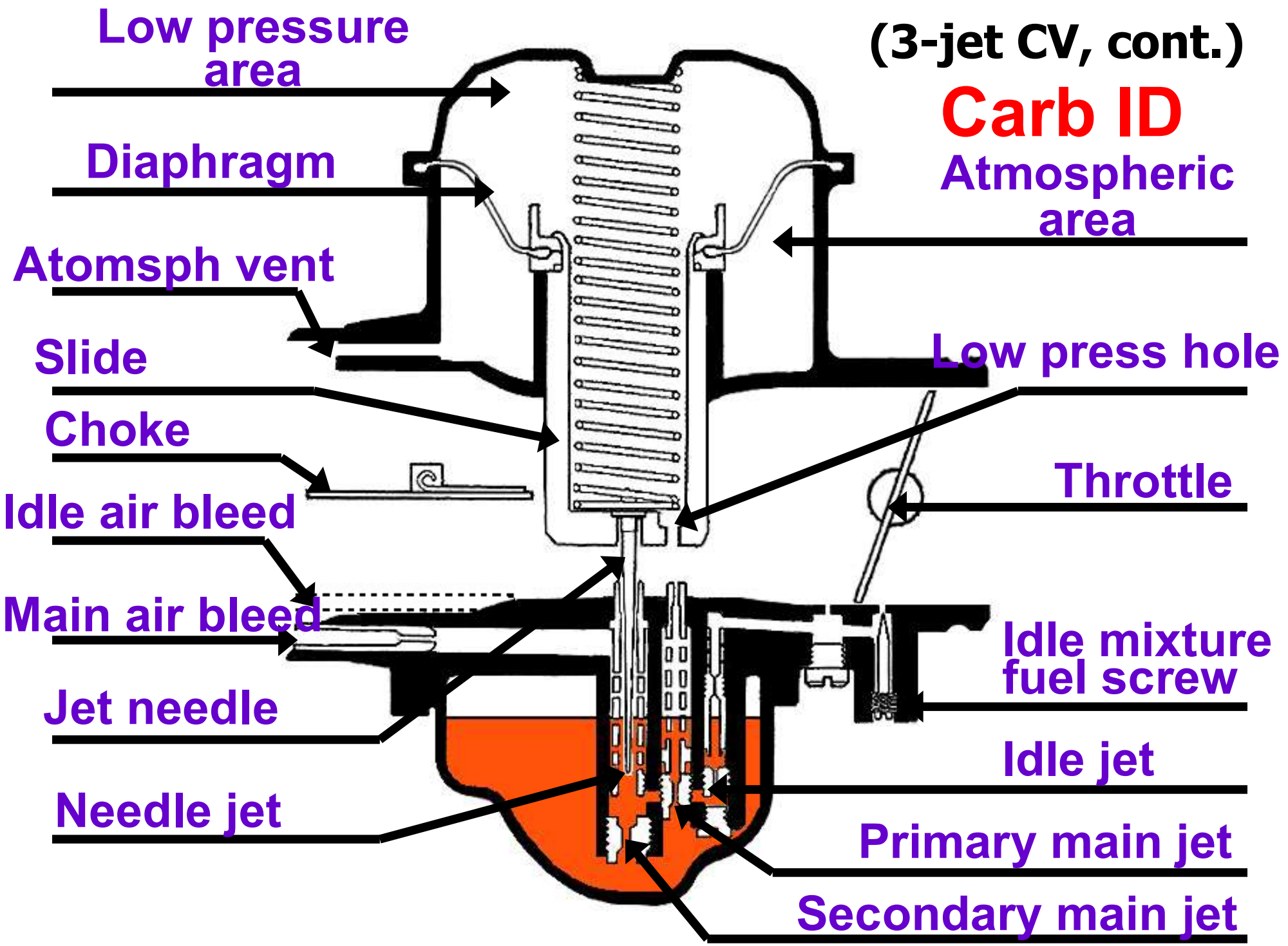
(3-jet CV, continued)

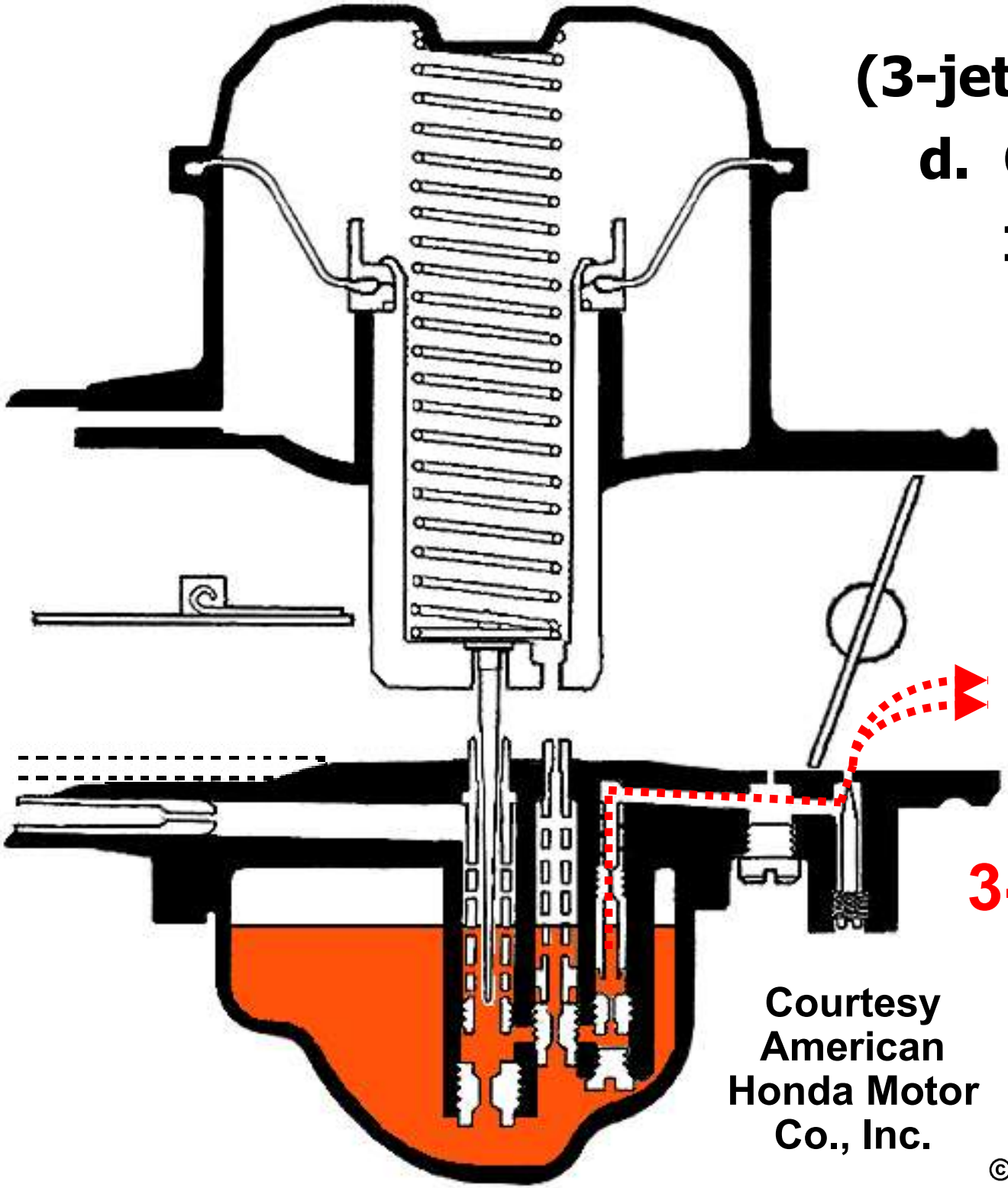
c. "Three jets"
   1) Idle
   2) Primary main
   3) Secondary main

Courtesy American Honda Motor Co., Inc..

(3-jet CV, cont.)

Carb ID



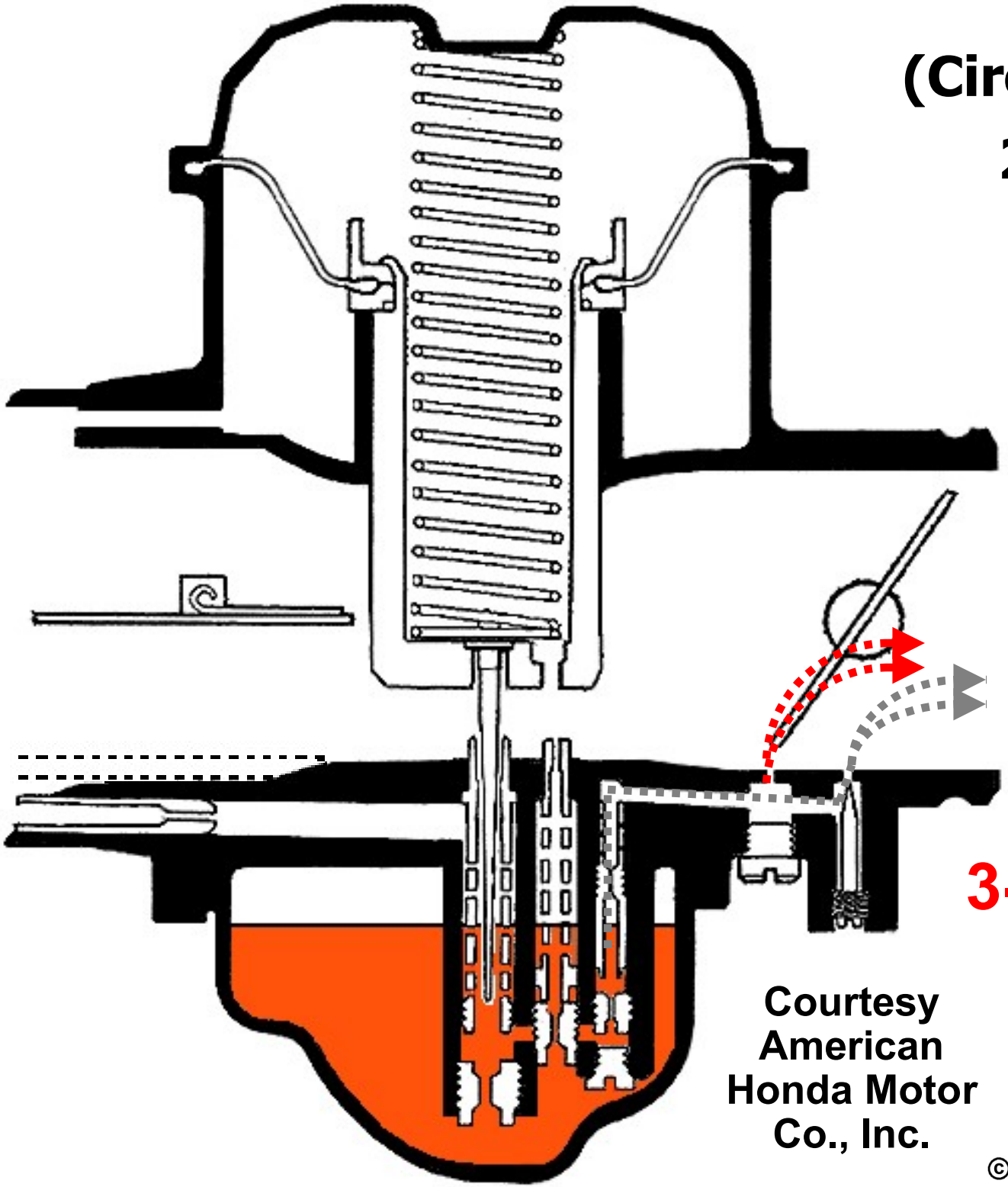


(3-jet CV, continued)

- d. Circuits
  - 1) Idle
    - a) 0-$^{1}/_{4}$ throttle
    - b) Always on

3-Jet CV

Courtesy American Honda Motor Co., Inc.



(Circuits, continued)

2) Transfer
   a) Just off idle
   b) Transition circuit
   c) Uncovered by throttle butterfly

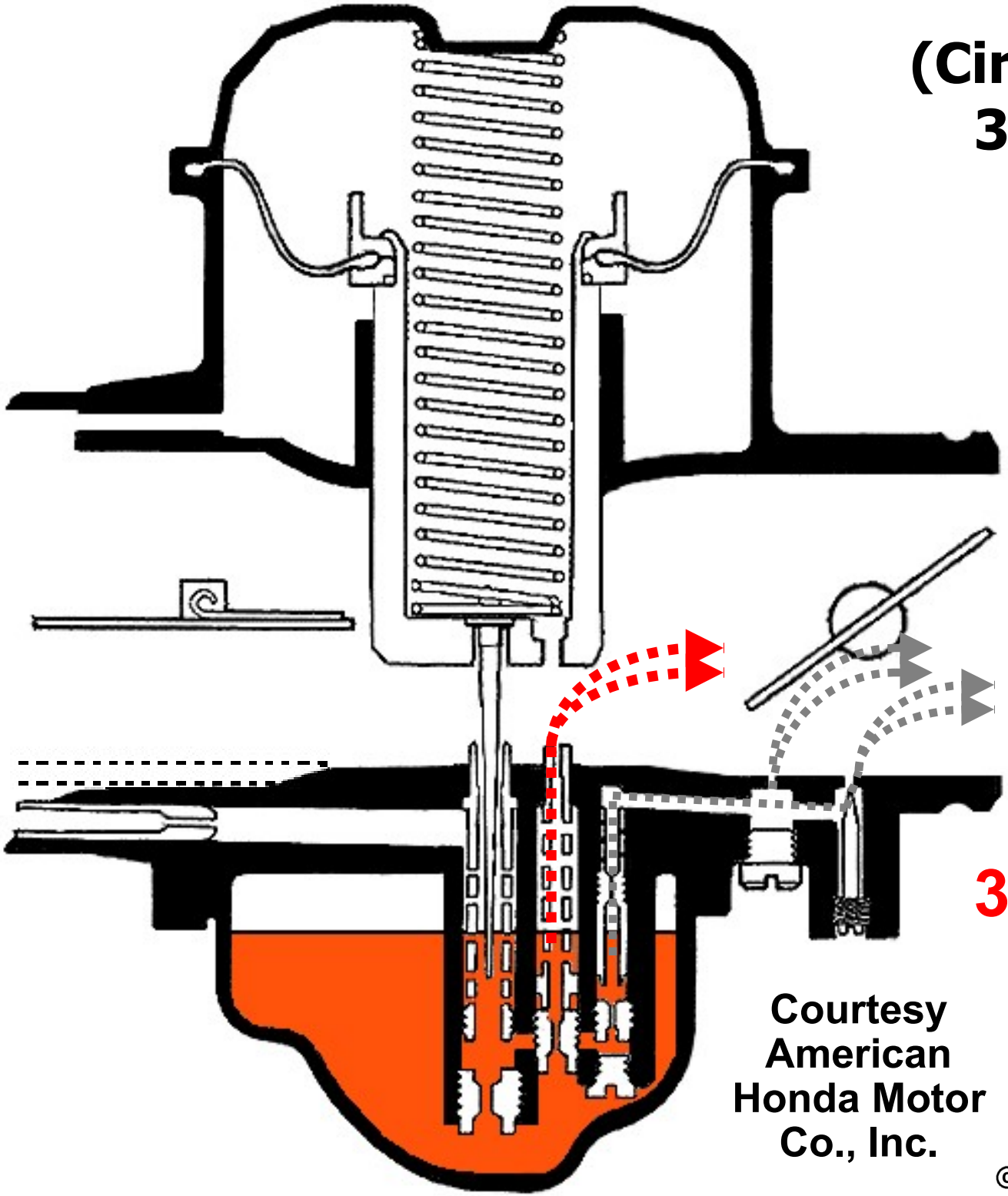
3-Jet CV

Courtesy American Honda Motor Co., Inc.

(Circuits, continued)

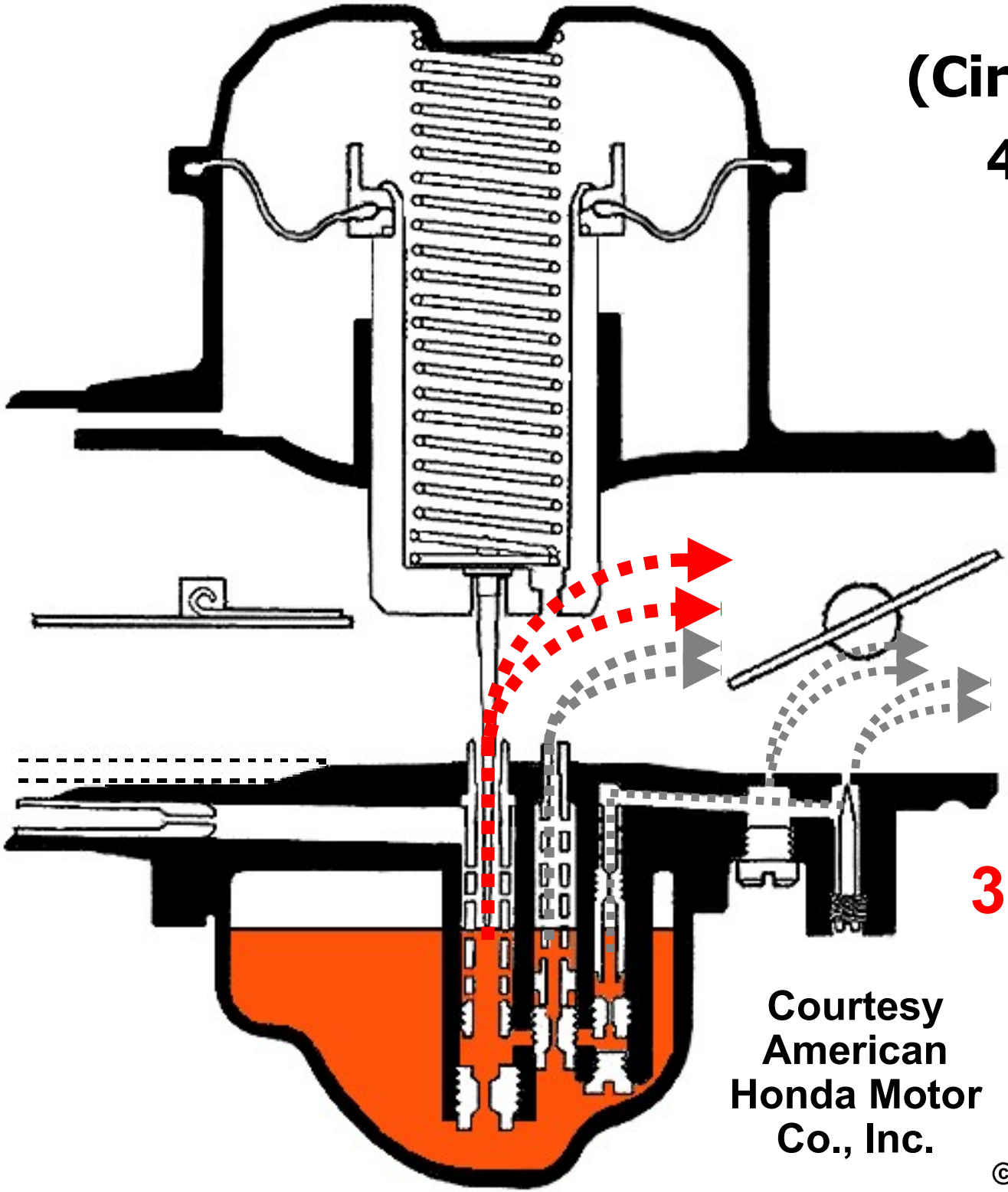
3) Primary main

a) $^{1}/_{4}$-$^{1}/_{2}$ throttle



3-Jet CV

Courtesy American Honda Motor Co., Inc.

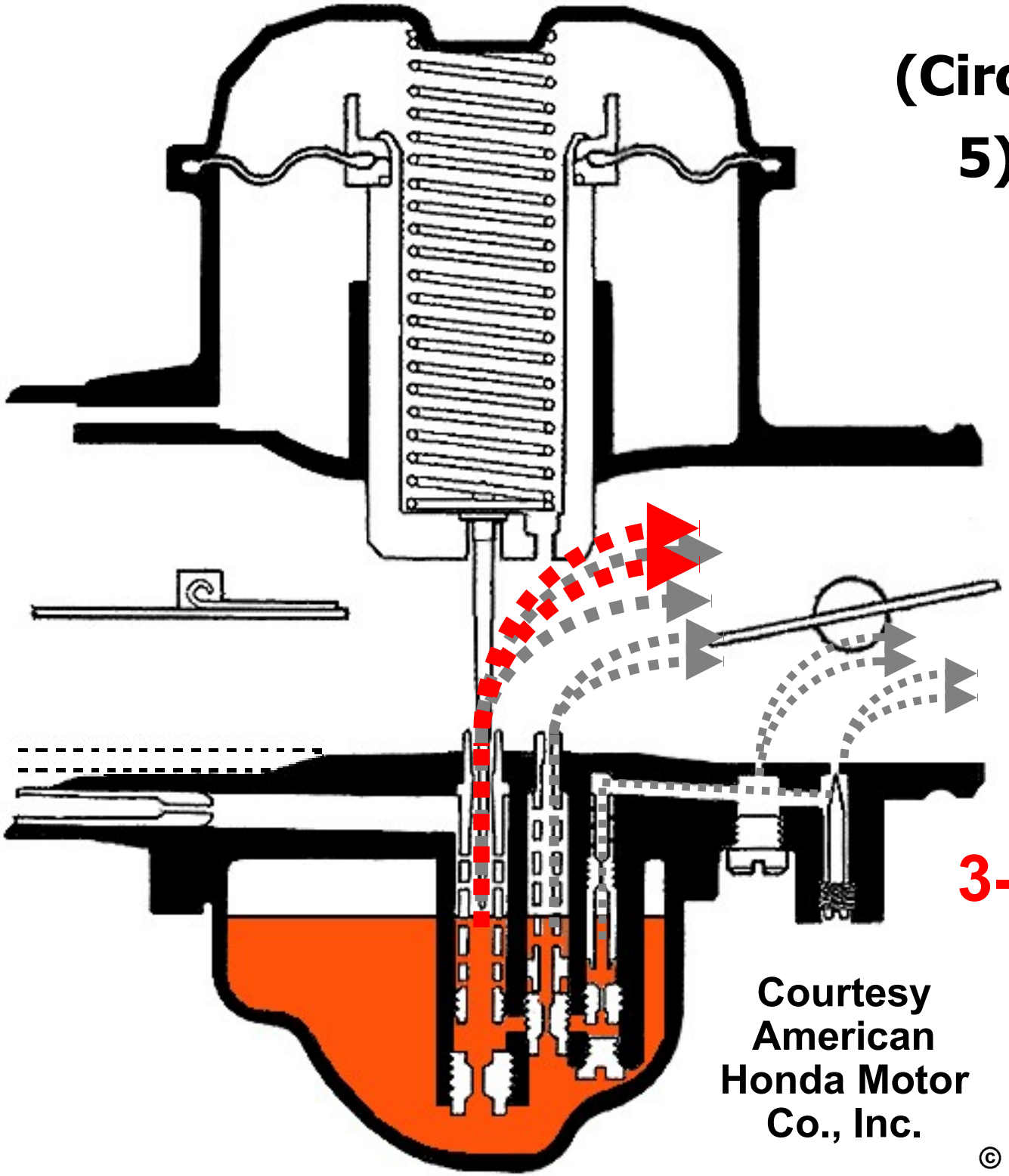


(Circuits, continued)

4) Needle jet
   a) $^{1}/_{2}$-$^{3}/_{4}$ throttle
   b) Widest range
   c) Most ridden

3-Jet CV

Courtesy American Honda Motor Co., Inc.



(Circuits, continued)

5) Secondary main

a) $^{3}/_{4}$-WOT

b) Equal to main jet on other carbs

c) Secondary main jet the final fuel flow restriction

3-Jet CV

Courtesy American Honda Motor Co., Inc.

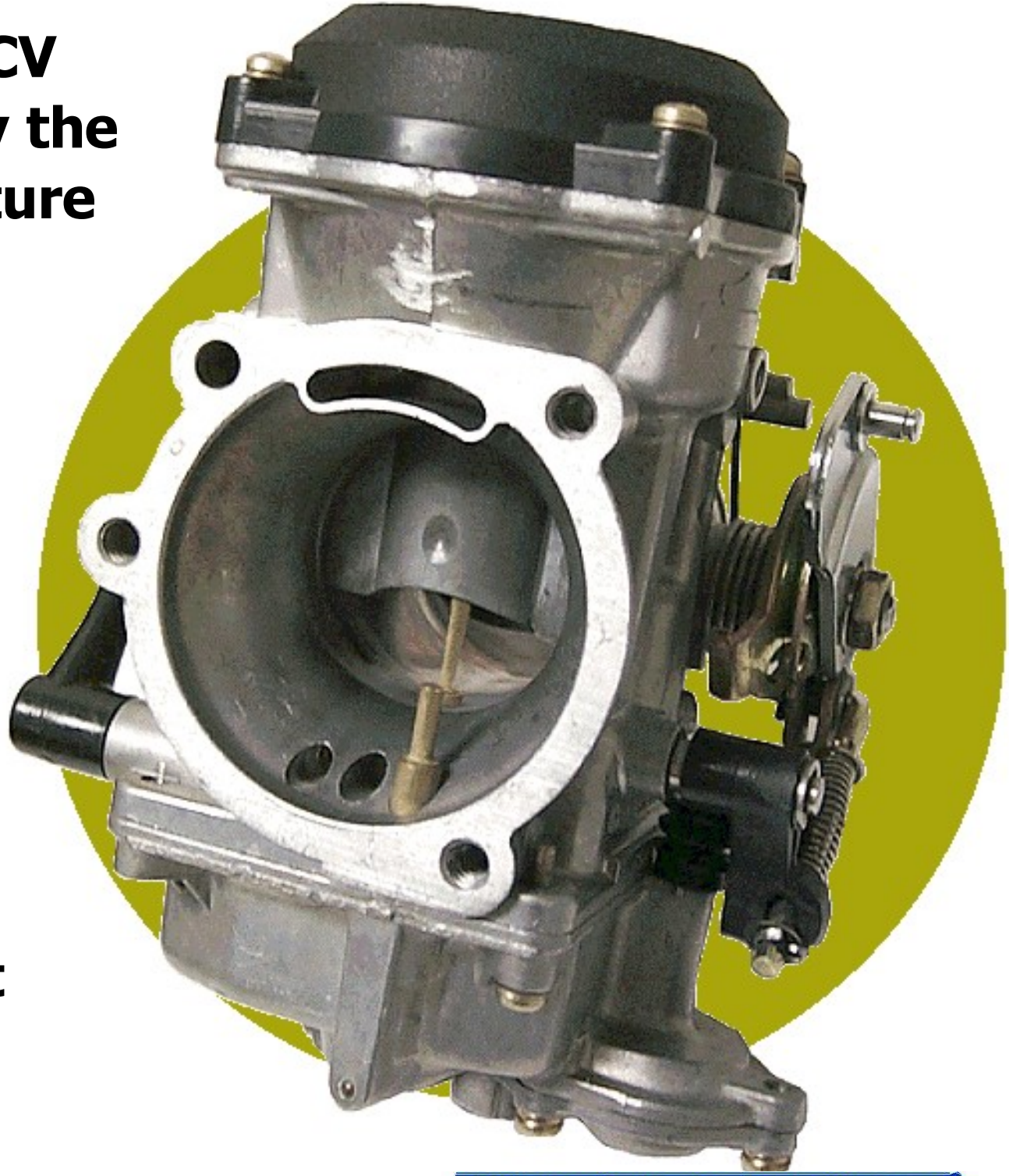
14. Benefits of the CV

a. Delivers only the air/fuel mixture the engine needs, and only when it needs it

b. Altitude compen-sating

c. Superior throttle response

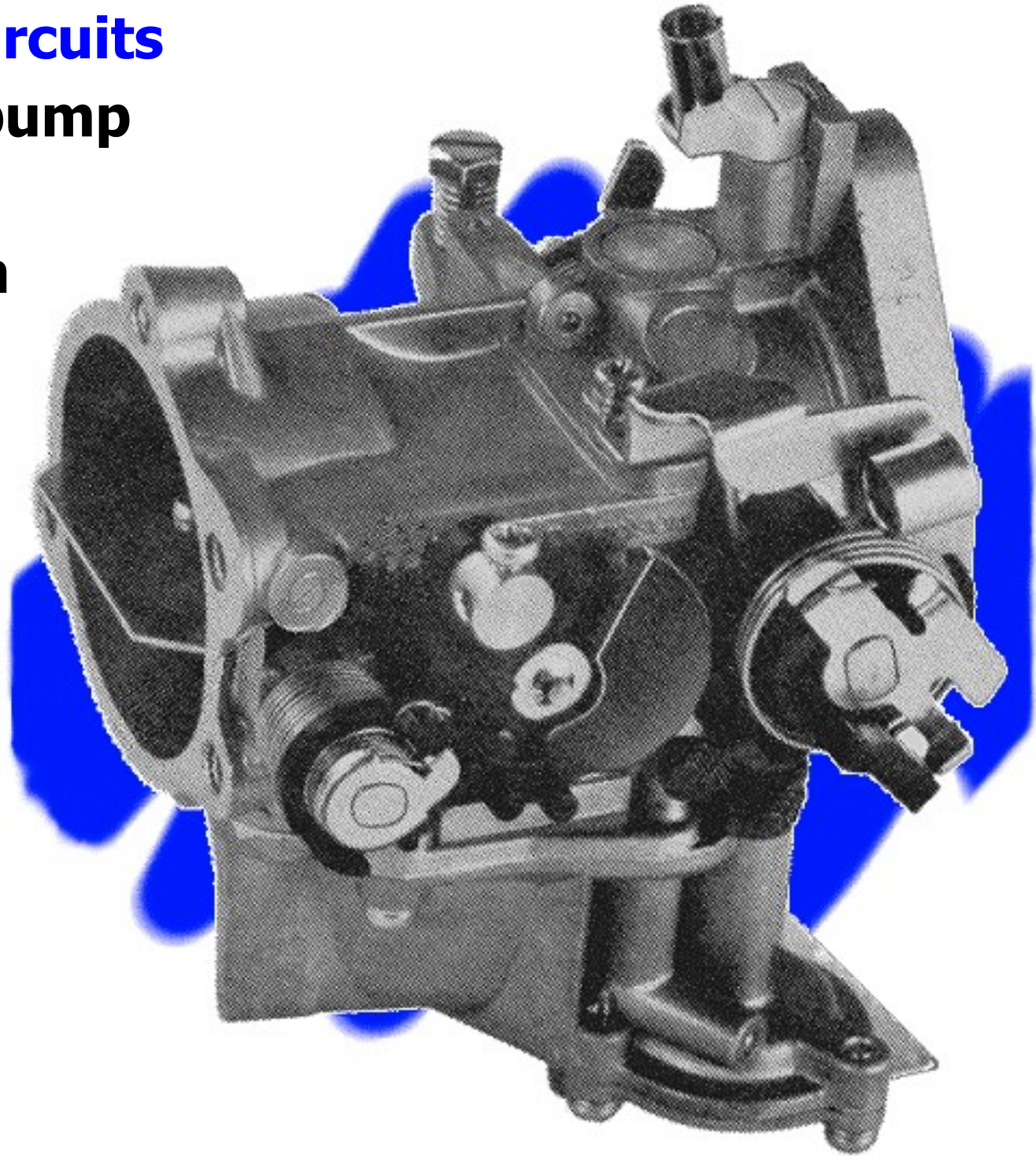
d. Low exhaust emissions



IV. Supplemental Circuits

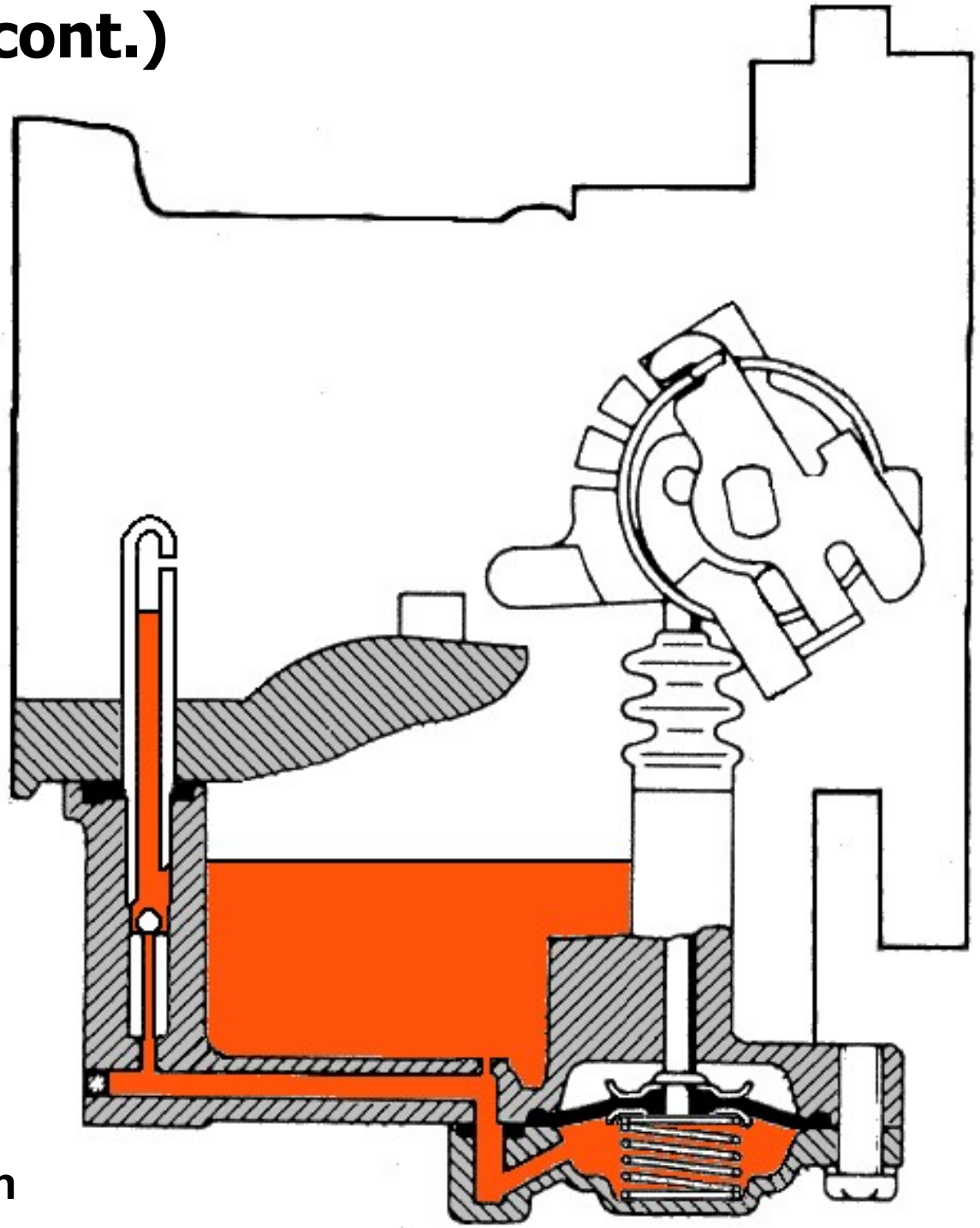
A. Accelerator pump

1. One-shot, diaphragm type fuel pump
2. Prevents leanness on accel-eration



(Accelerator pump, cont.)

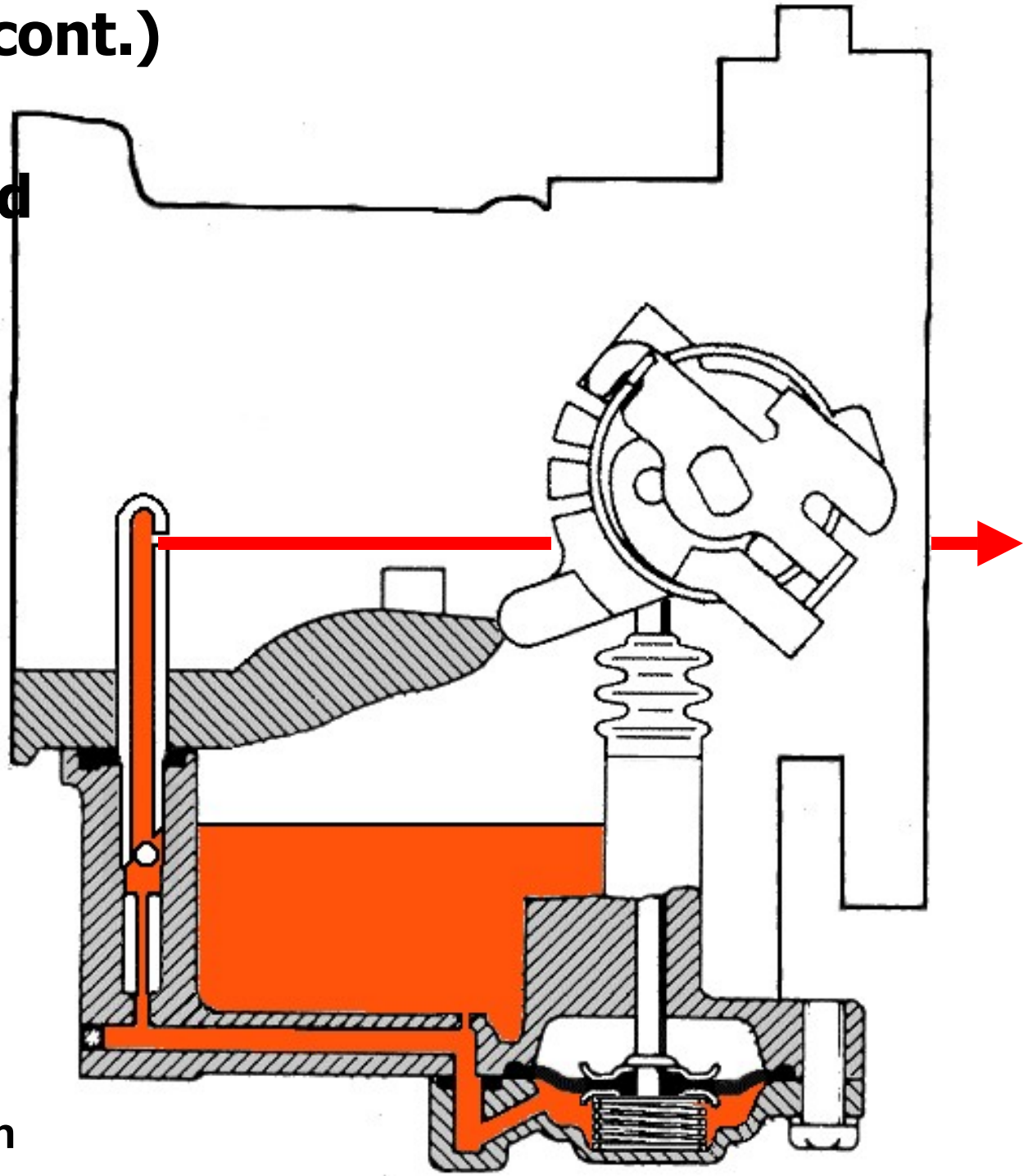
3. Throttle is connected to a plunger
4. Plunger is attached to a diaphragm pump
5. Output nozzle on air filter side of carburetor



Courtesy
Harley-Davidson
Motor Co.

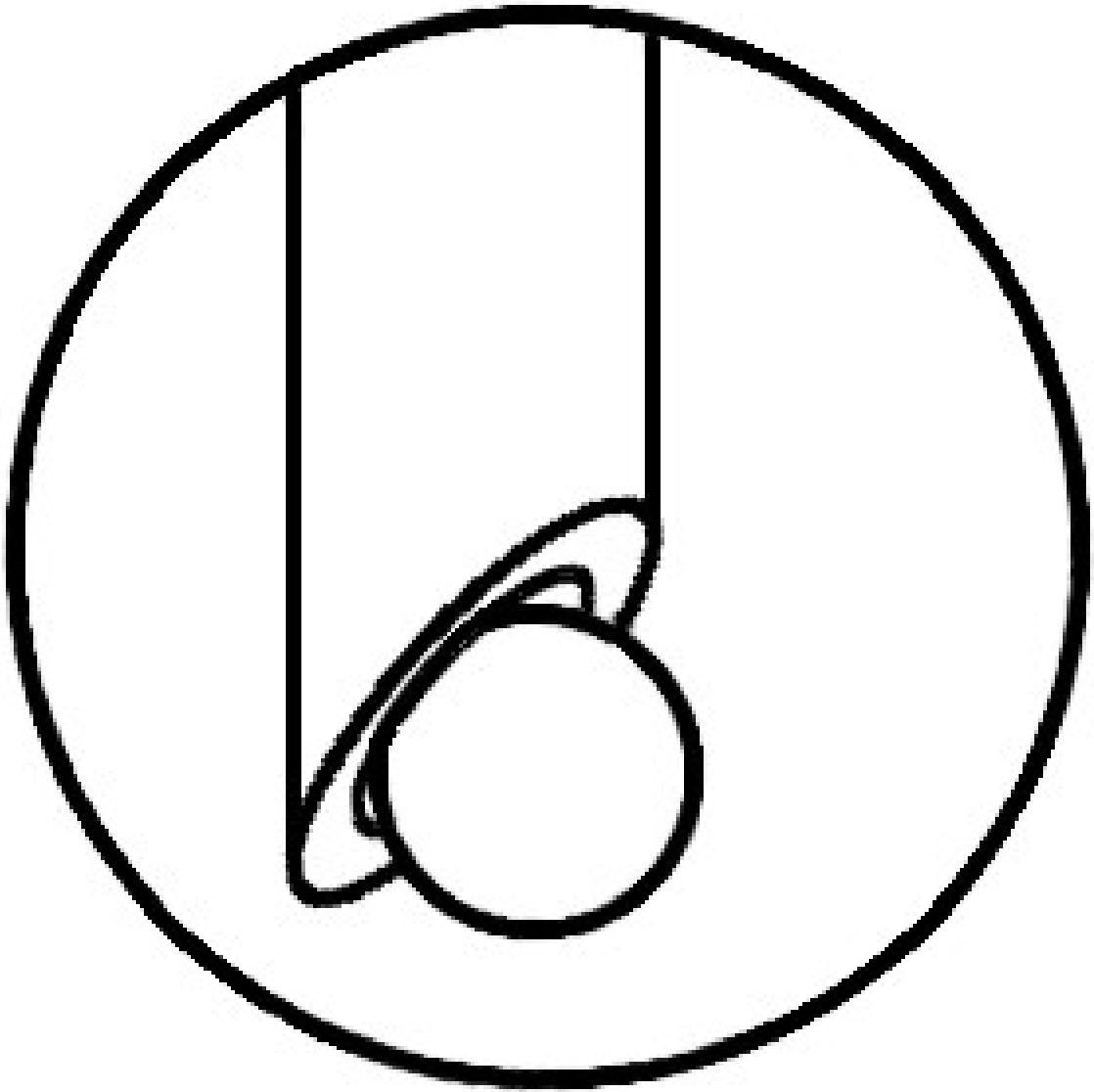
(Accelerator pump, cont.)

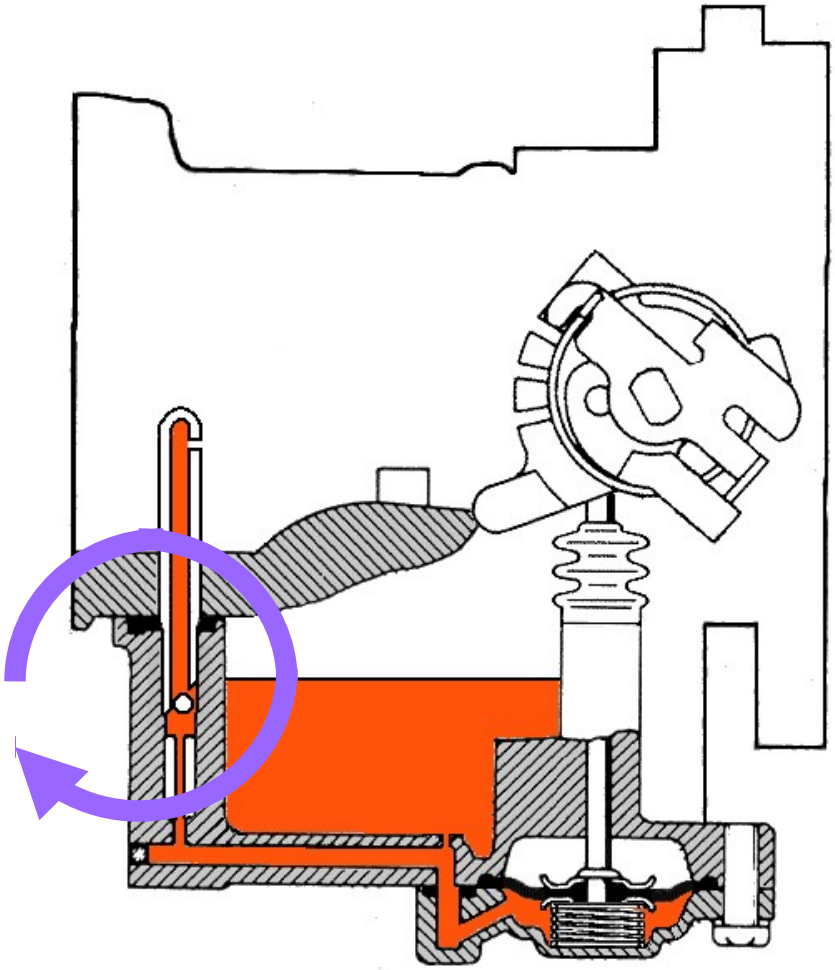
6. Accelerator pump activated by throttle linkage
7. At initial throttle opening, pump forces fuel past check ball



Courtesy
Harley-Davidson
Motor Co.

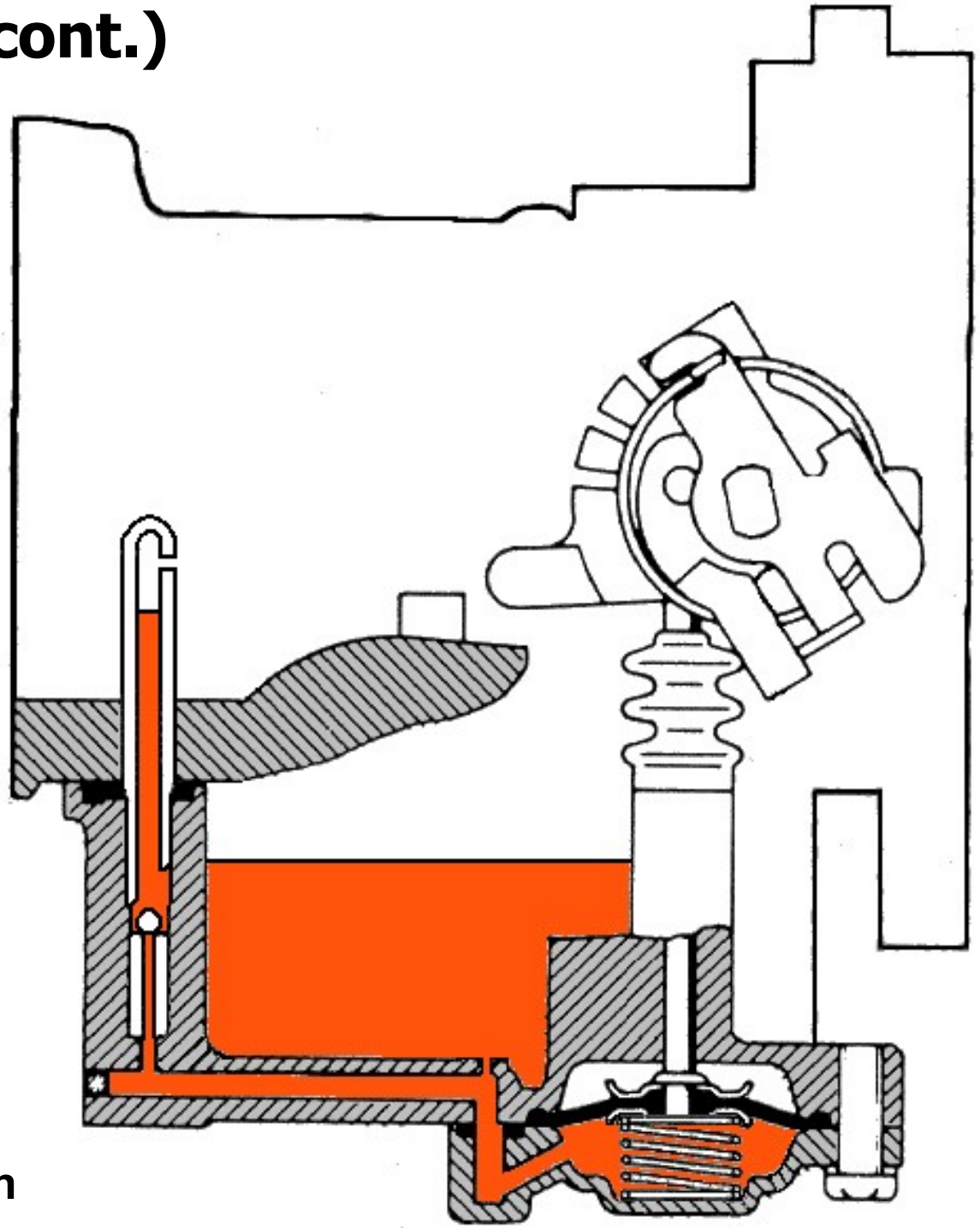
(Accelerator pump, cont.)





(Accelerator pump, cont.)

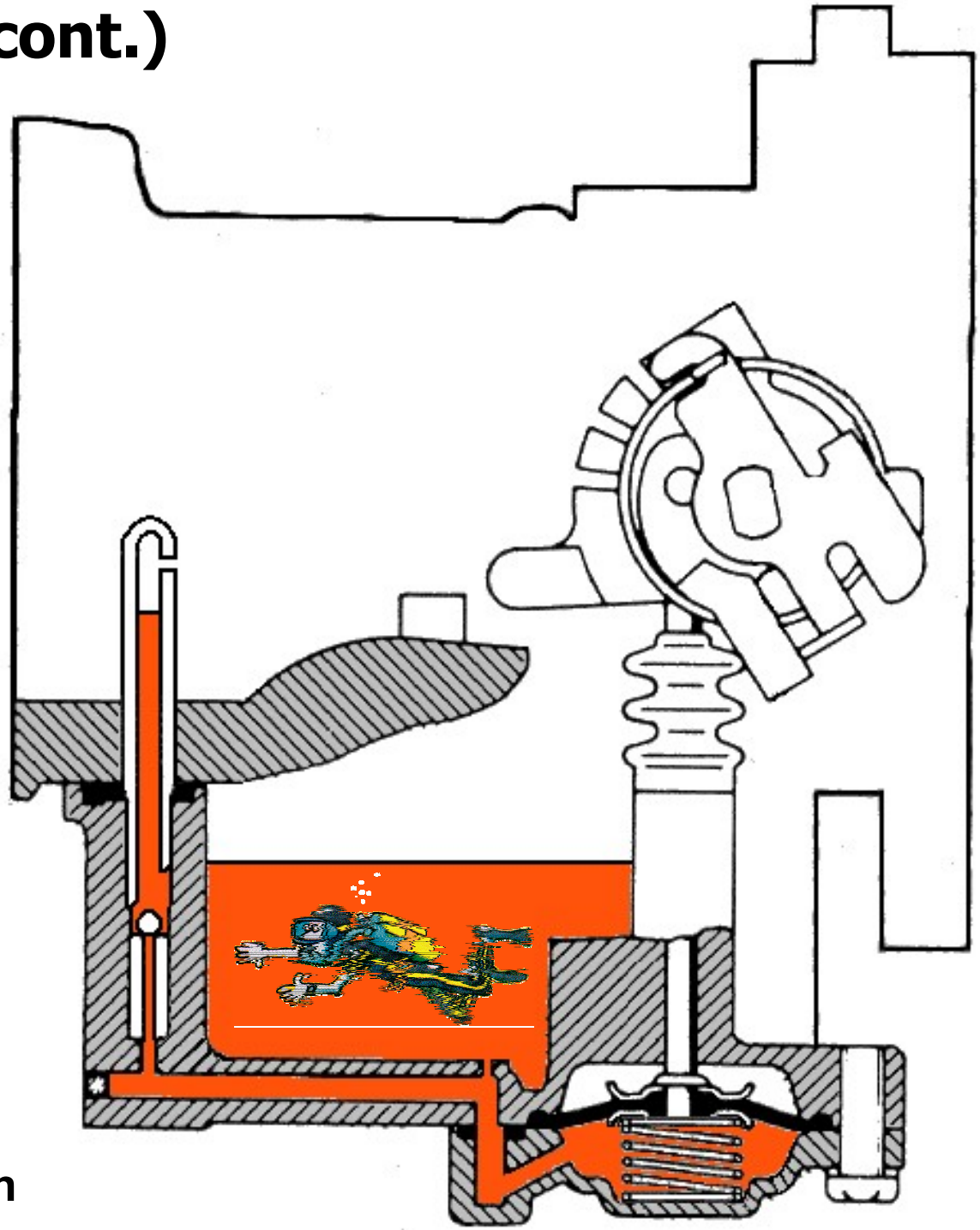
8. When the throttle is rolled back, the pump draws fuel from the float bowl



Courtesy
Harley-Davidson
Motor Co.

(Accelerator pump, cont.)

9. Check ball prevents reverse fuel flow, aids in replenishing pump, and helps maintain standing fuel in the spray nozzle

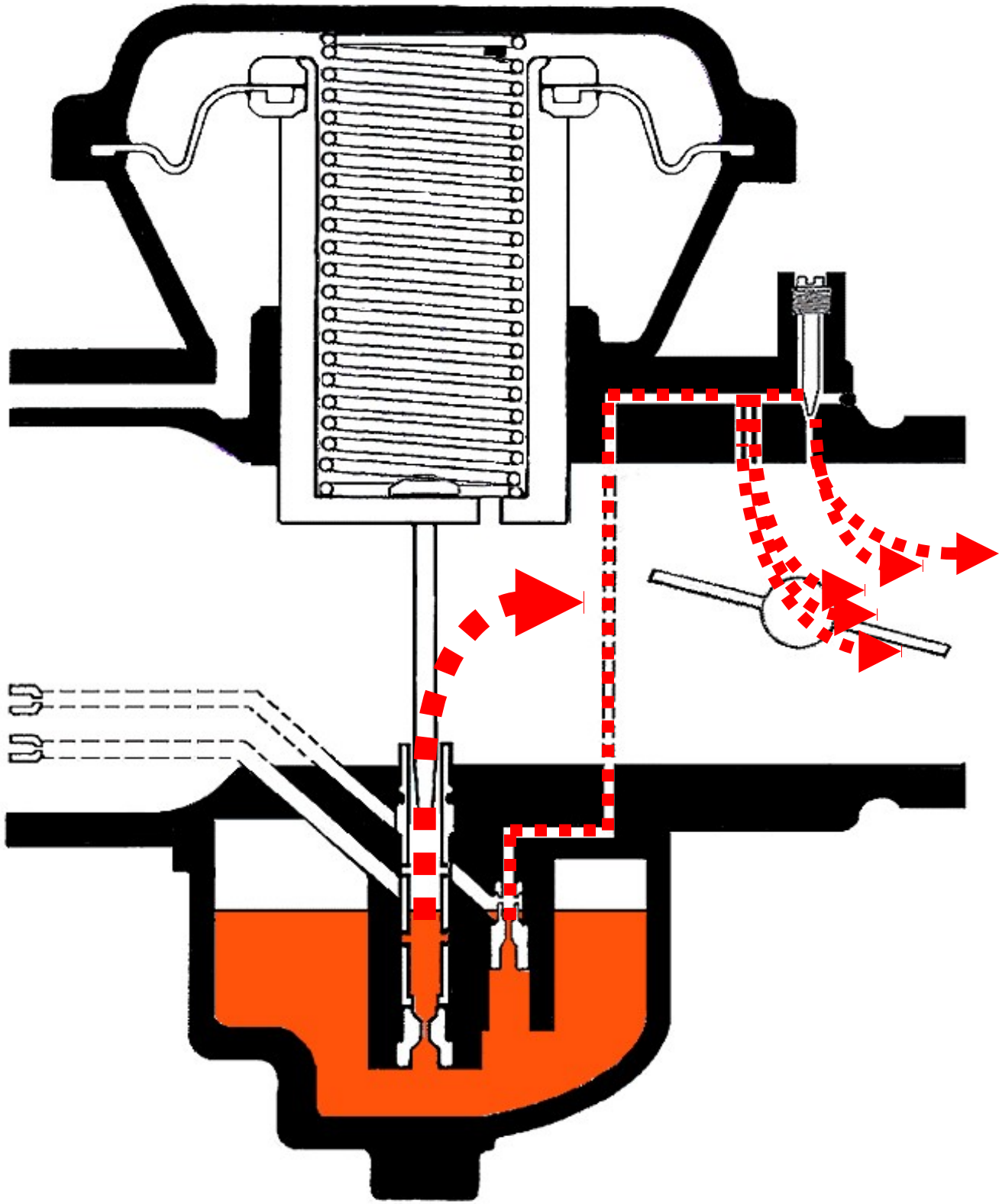


Courtesy
Harley-Davidson
Motor Co.

(Supplemental Circuits, cont.)

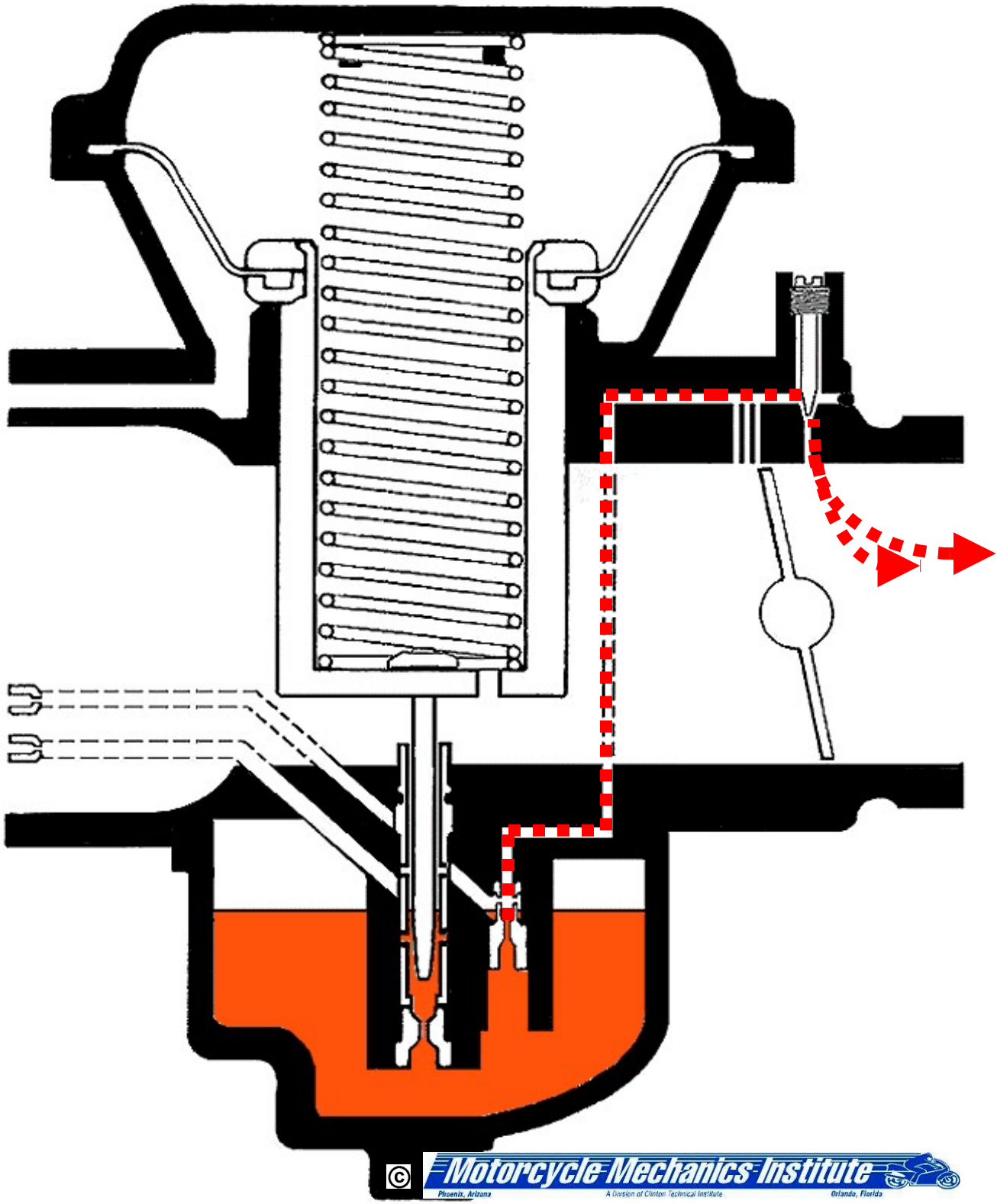
B. Air cut valve

1. **Prevents afterburn on decel-eration**
2. **At high rpm, strong "signal" at venturi, lot of fuel discharge**



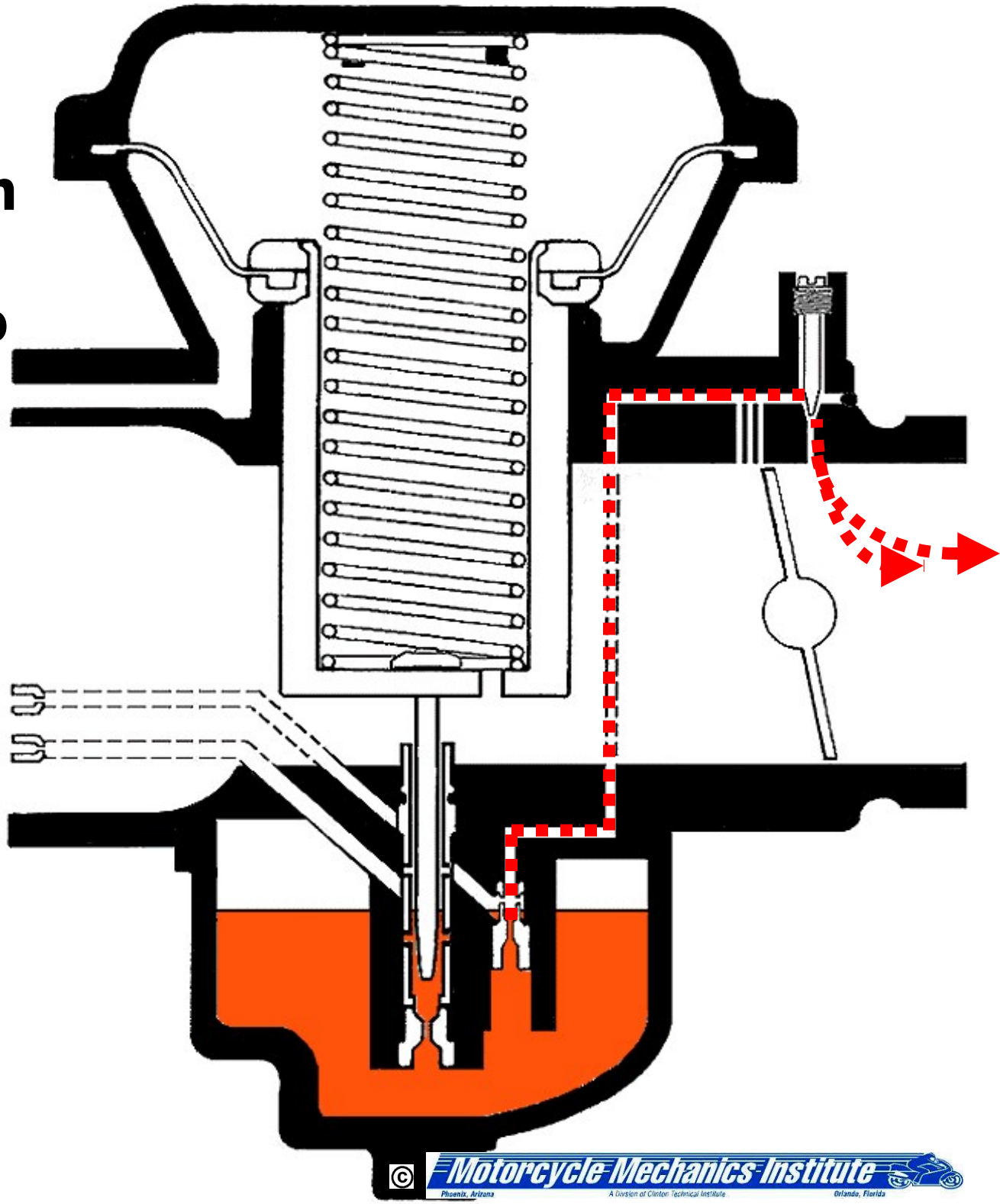
(Air cut valve, cont.)

3. When the throttle is suddenly closed, the engine is still momentarily at high rpm
4. Late model emissions spec idle circuits can't flow enough, the mixture is therefore too lean to burn



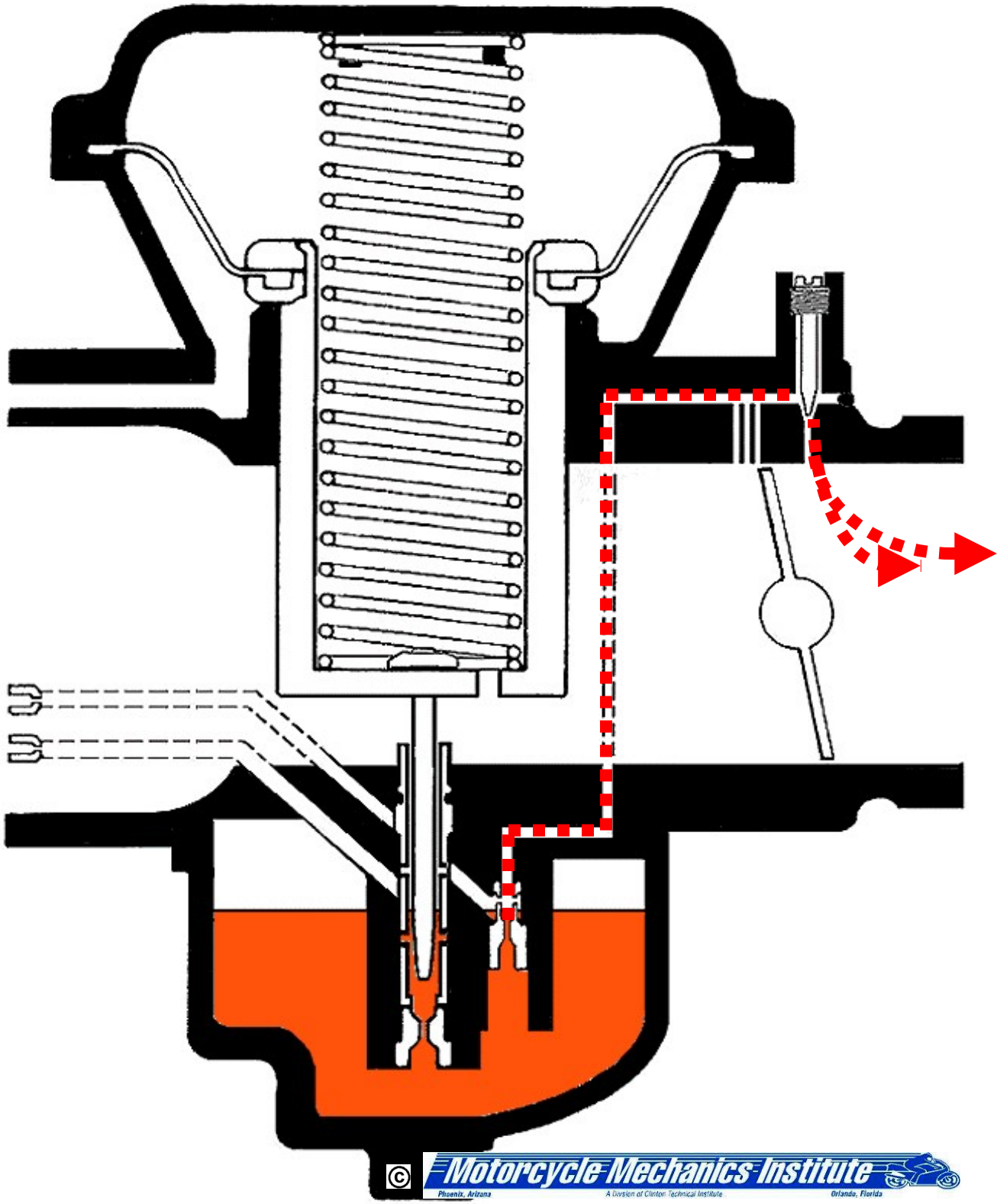
(Air cut valve, cont.)

5. The mixture passes through the engine un-burnt, and into the exhaust
6. The mixture combines with hydrocarbons already in the exhaust, be-comes burn-able, and ignites from the exhaust's heat



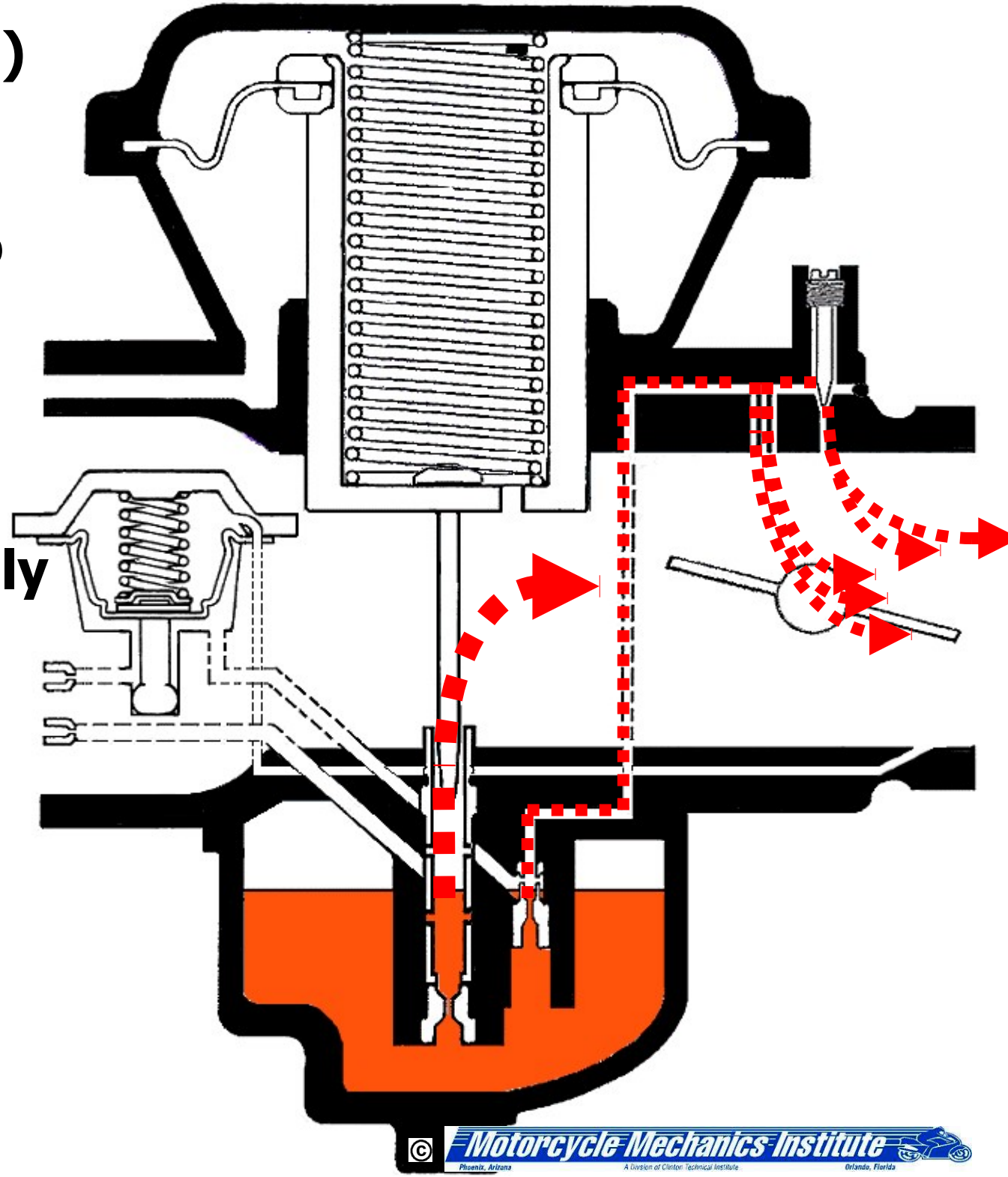
(Air cut valve, cont.)

7. This afterburn in the exhaust is audible as a popping sound



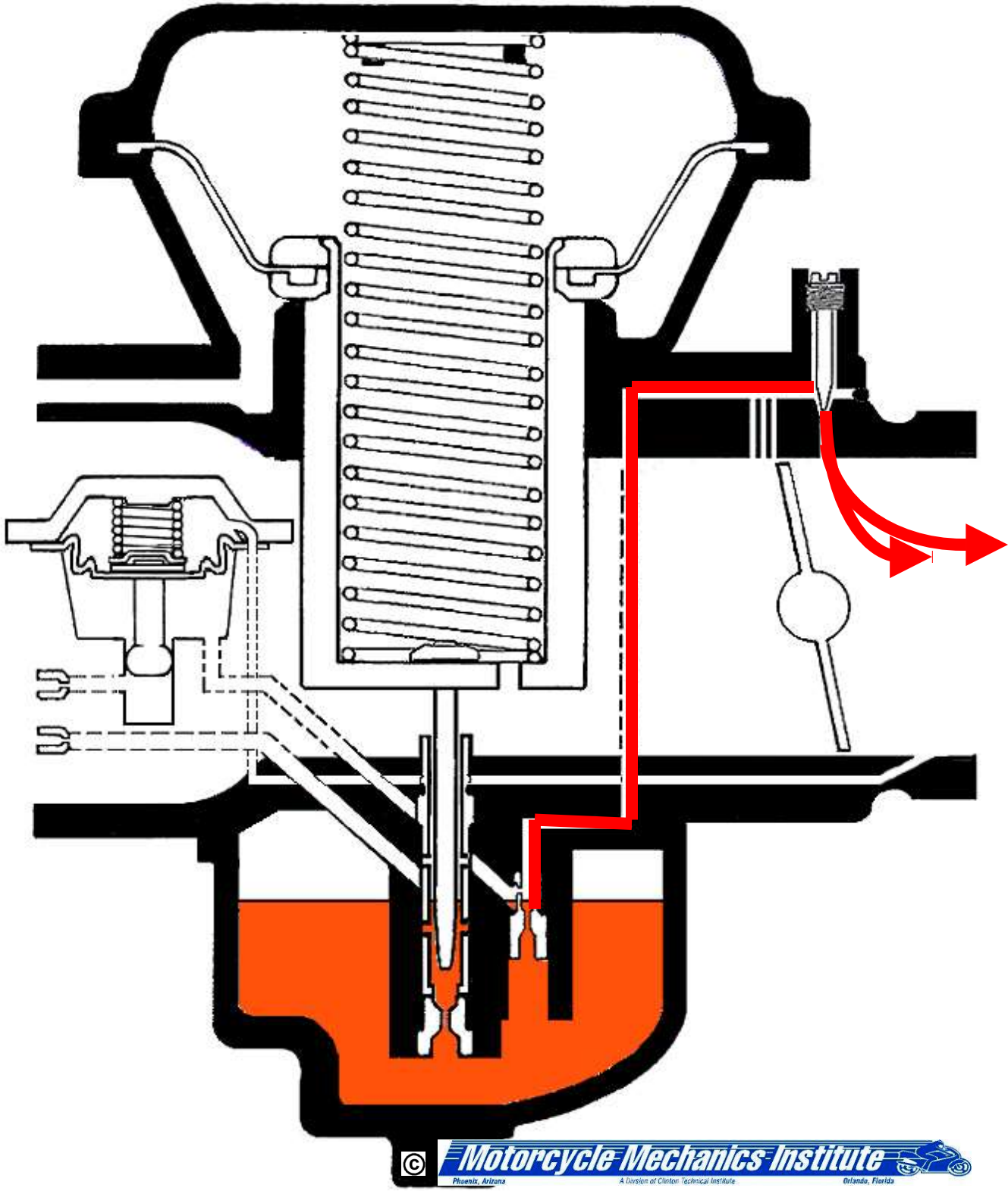
(Air cut valve, cont.)

8. The air cut valve is plumbed into the idle circuit's air bleed
9. The air bleed works normally most of the time



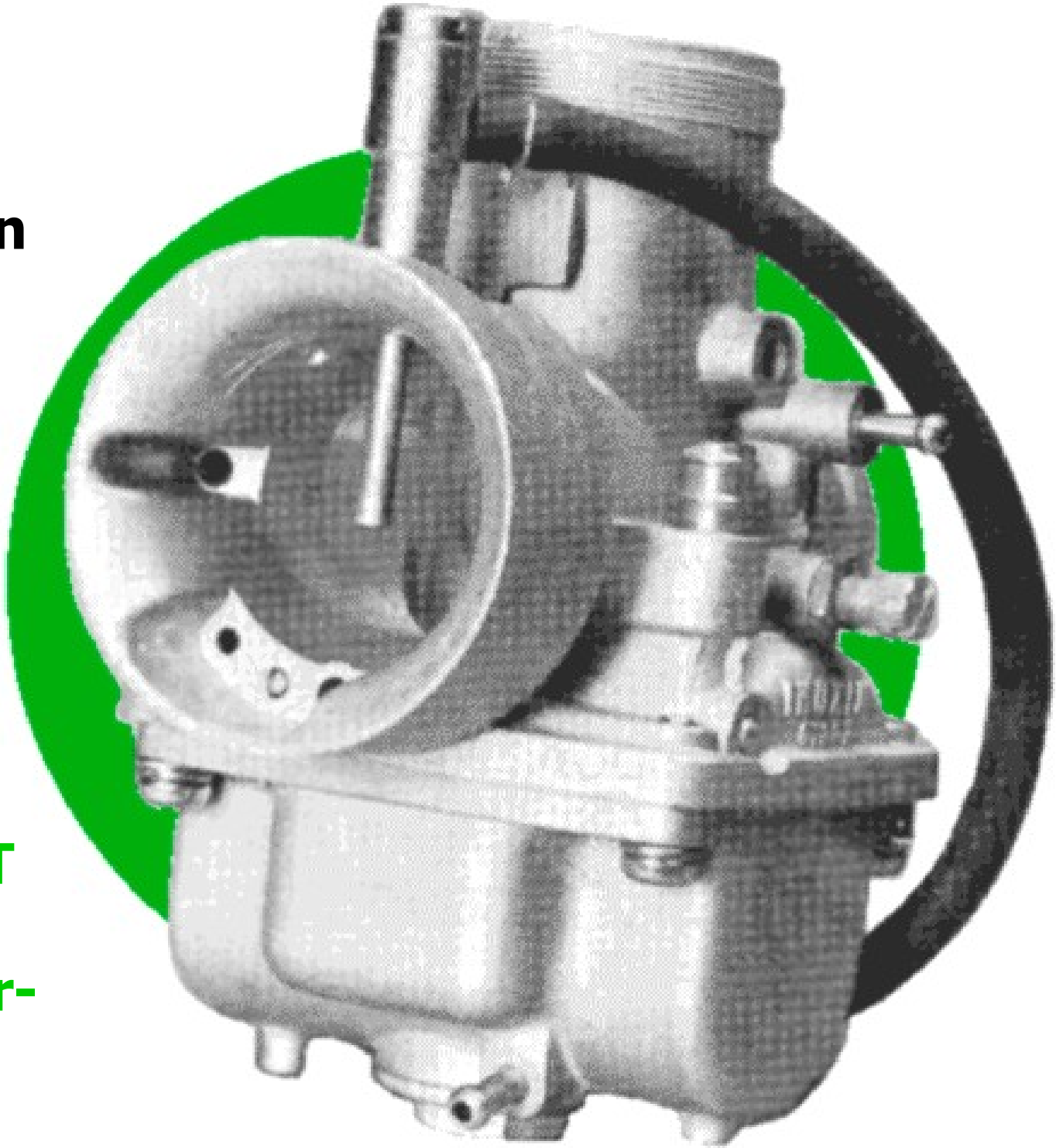
(Air cut valve, cont.)

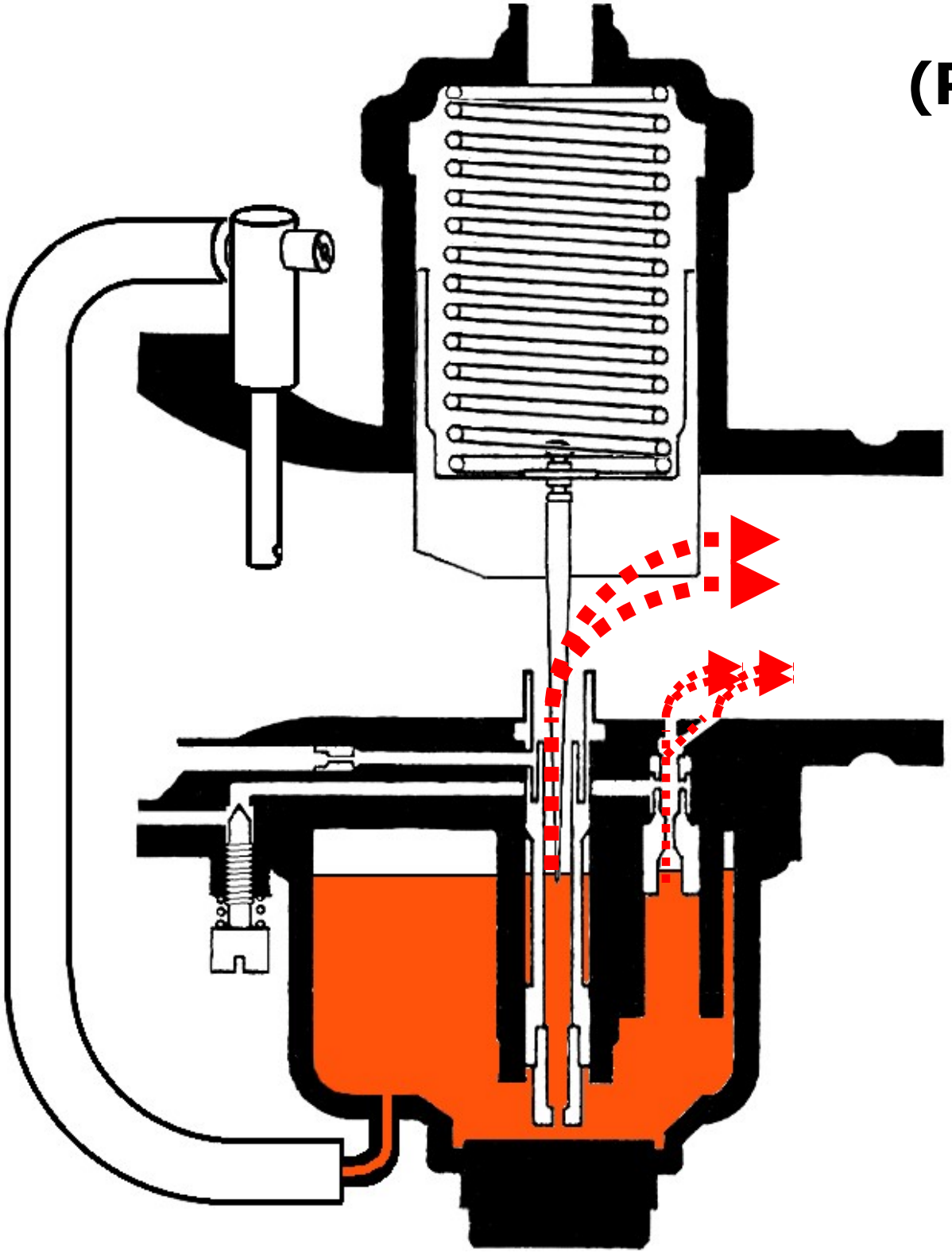
10. But when the throttle is closed from high rpm, the air cut valve closes the idle air bleed, greatly richening the idle discharge
11. Air cut valve is controlled by engine vacuum



(Supplemental Circuits, cont.)

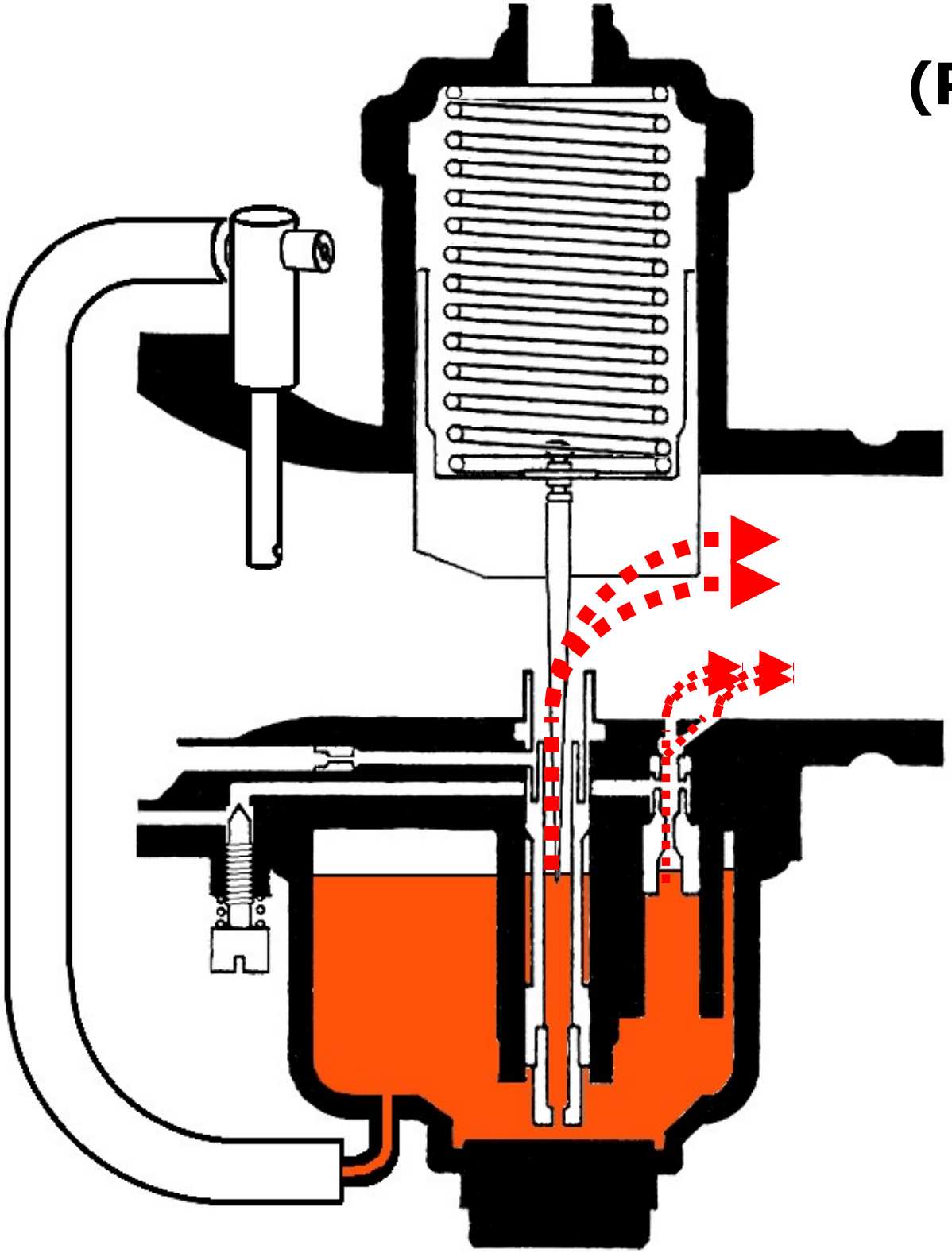
C. Powerjet
   1. A post-main circuit
   2. Allows jetting main lean for good acceler-ation, yet having enough fuel at WOT to avoid engine over-heating or seizure





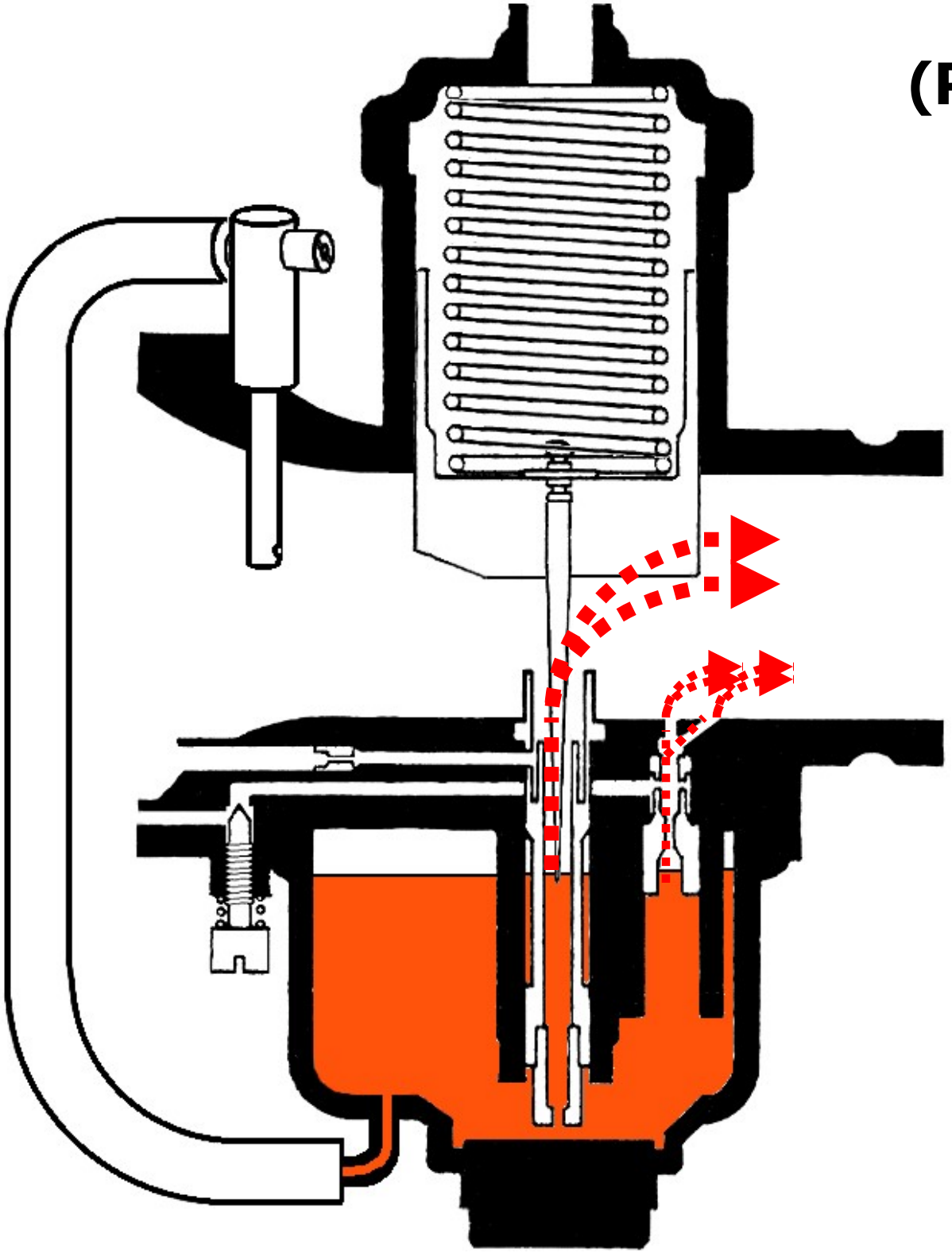
(Powerjet, cont.)

3. Originated on two-stroke road racers and snow-mobiles
4. Available after-market for any carburetor
   a. *Thunderjet*
   b. *Dialajet*



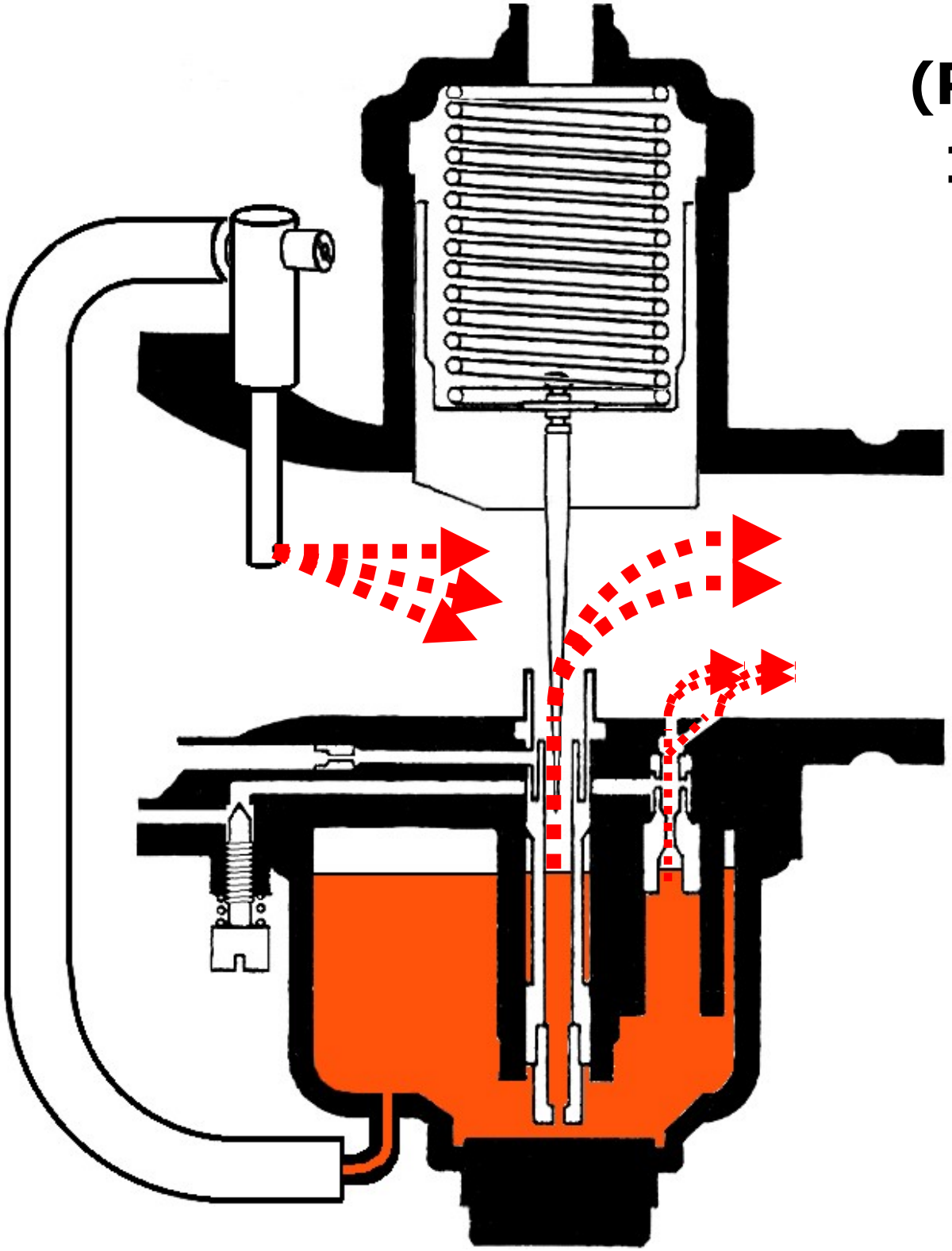
(Powerjet, cont.)

5. $^{7}/_{8}$-full throttle
6. The final circuit
7. Includes air bleed
   a. Some have replaceable air bleed jet
   b. Others have adjuster which adjusts air bleed opening
8. Discharge nozzle on air filter side of carburetor



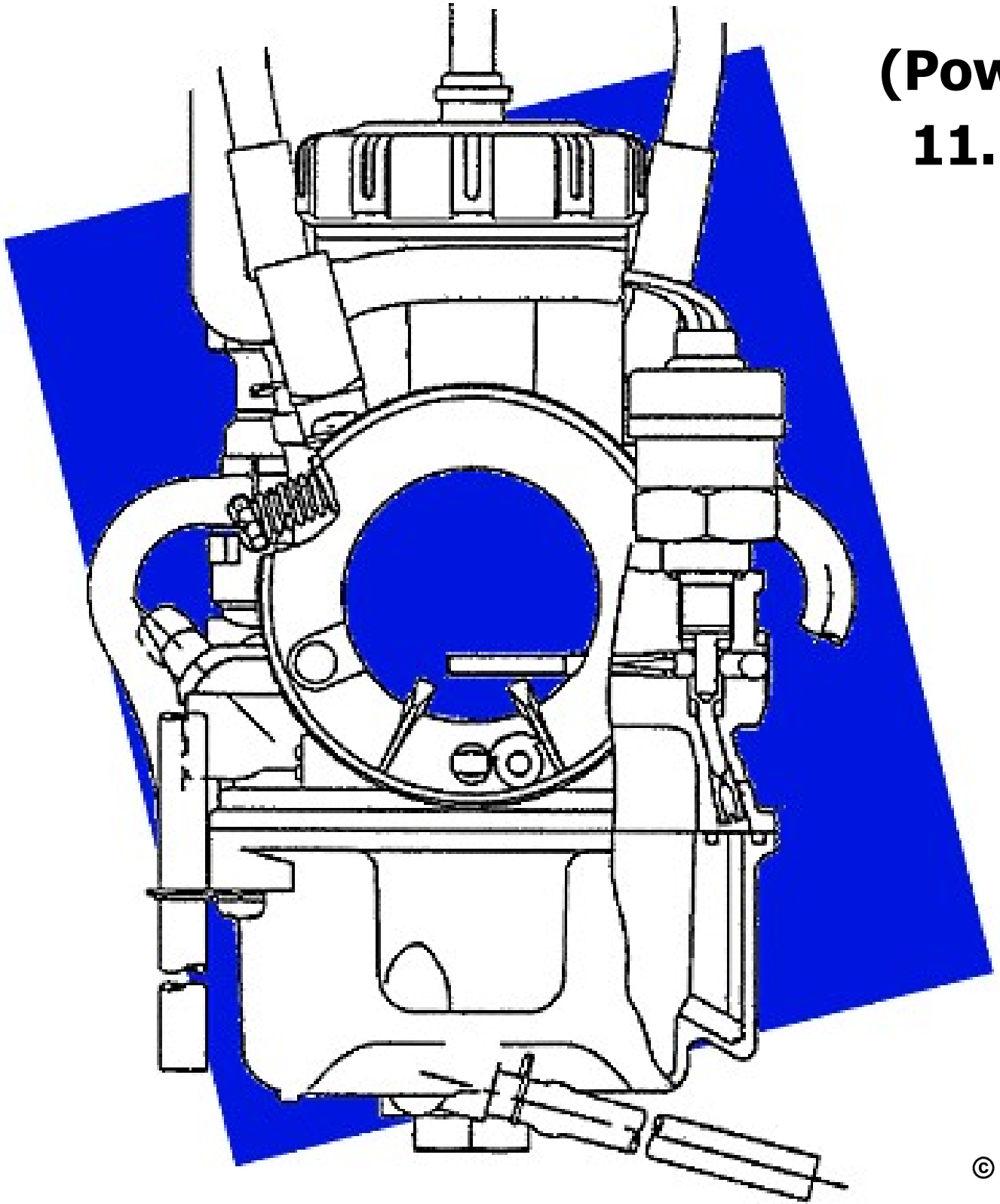
(Powerjet, cont.)

9. Works on pressure differences



(Powerjet, cont.)

10. Works on pressure differences



(Powerjet, cont.)

11. Current OEM version electrical, controlled by rpm data sent from ignition control module

Courtesy
Kawasaki
Motors Corp.

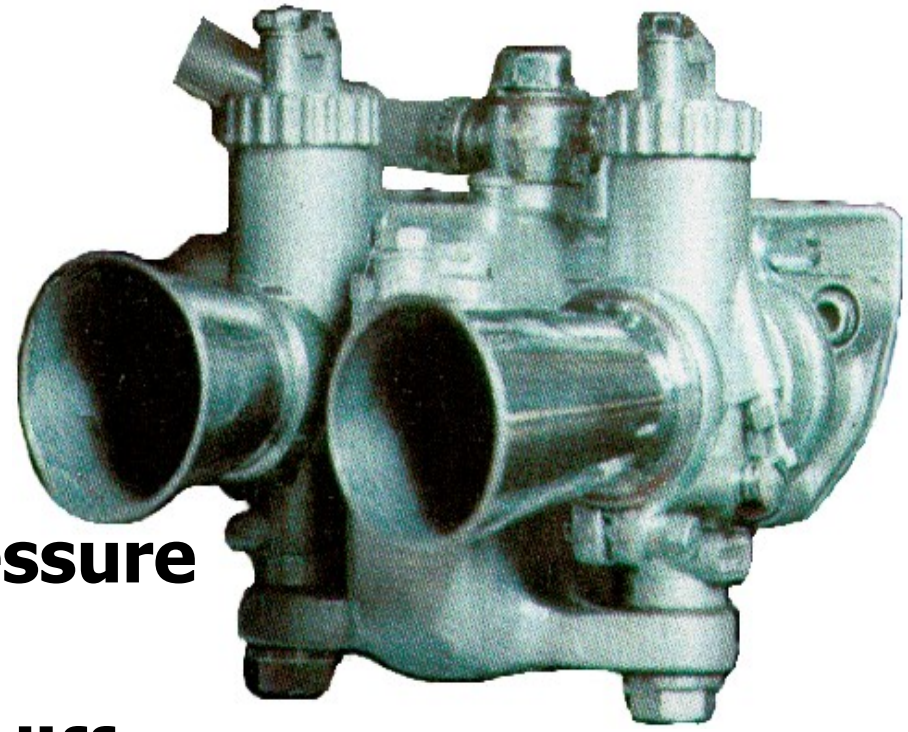
(Powerjet, cont.)

1992
Cagiva
500
GP

Carburetor Review

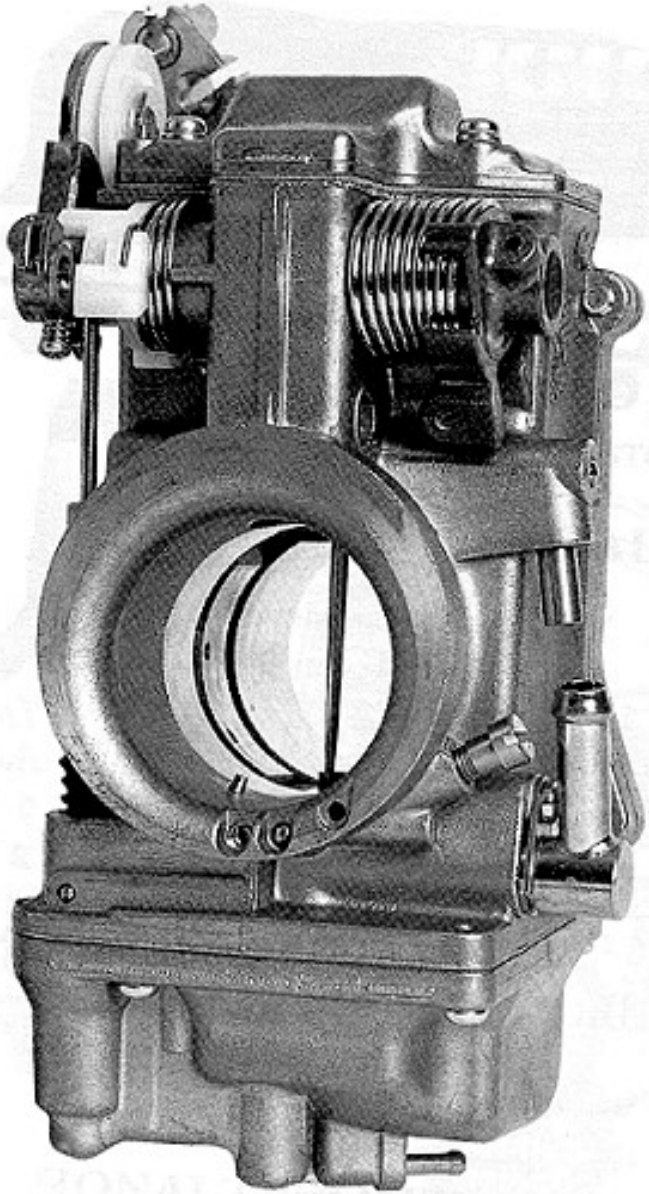
A. Carburetor Theory

1. Three jobs of carburetor
   a. Saturate intake air w/ hydrocarbons
   b. Meter this mixture in amounts and at ratios suitable to the engine
   c. Control engine rpm
2. Venturi principle
   a. Restriction in a tube
   b. More speed, less pressure
3. Pressure differences
   a. More air flow, more difference
   b. Pushes the fuel



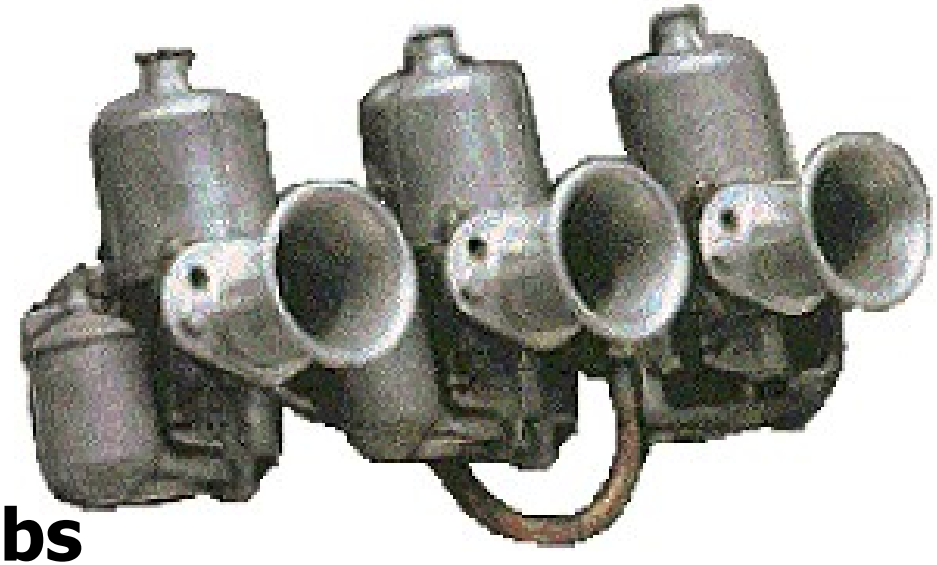
(Review, continued)

B. The Basic Carburetor



1. Three basic circuits
   a. Idle ("pilot," "slow")
   b. Midrange (most ridden circuit)
   c. Main
2. Jets
   a. Added-on fuel tube restrictions
   b. Not always replaceable
3. Air bleeds
   a. The "Y" principle
   b. Ensure adequate atomization
   c. Midrange circuit usually shares another circuit's air bleed
4. Idle mixture screws
   a. Fuel: In = lean, out = rich
   b. Air: In = rich, out = lean

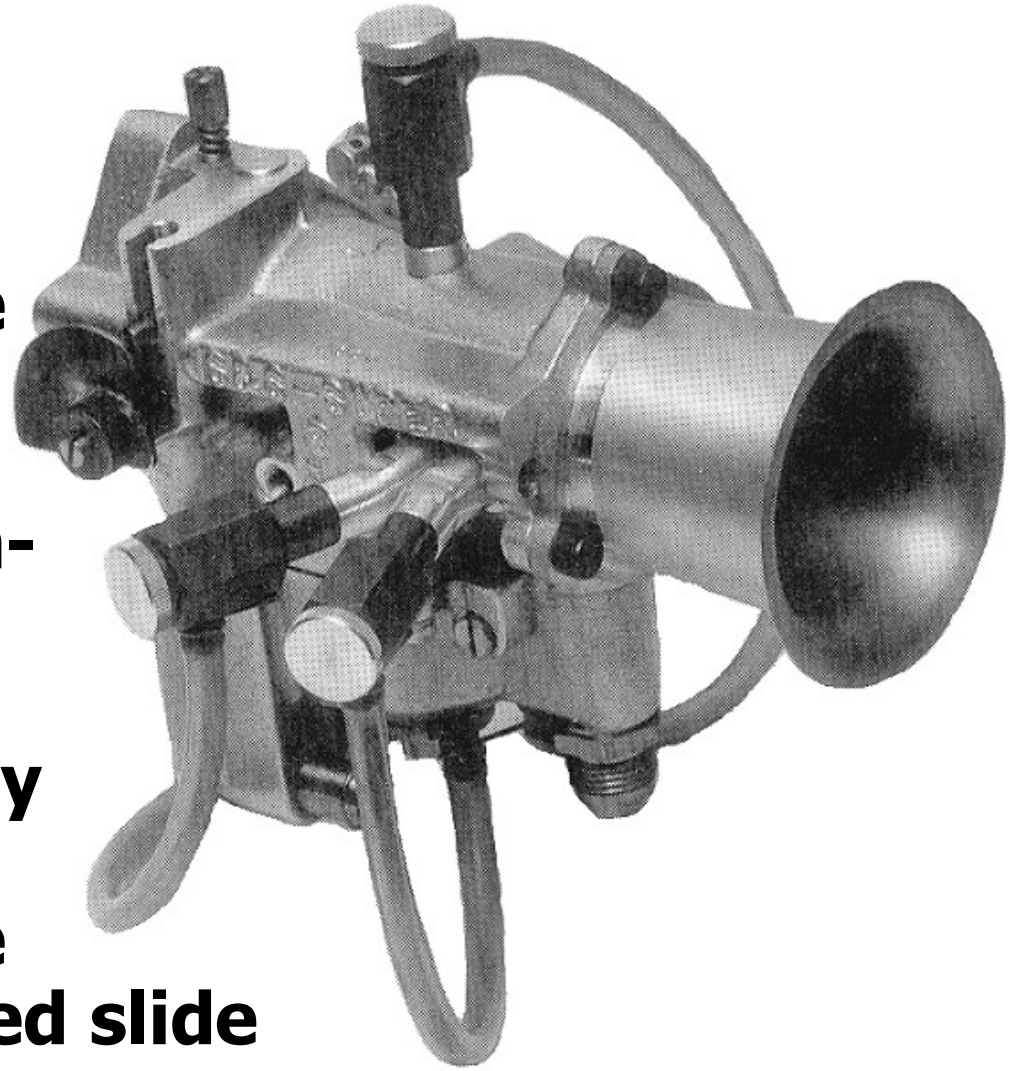
(The Basic Carburetor, cont.)



5. Transfer ports
   a. Transition off idle
   b. Part of idle circuit
   c. Controlled by throttle
      1) Butterfly on fixed venturi and CV carbs
      2) Slide on mechanical slide carb
6. Float system
   a. Affects all circuits
   b. Float height usually adjustable
7. Cold starting system
   a. Tickler: works best w/ throttle open
   b. Choke: works best w/ throttle open
   c. Enrichener: works best w/ throttle closed
8. Mounting styles
   a. Spigot
   b. Flange
   c. Clamp-on

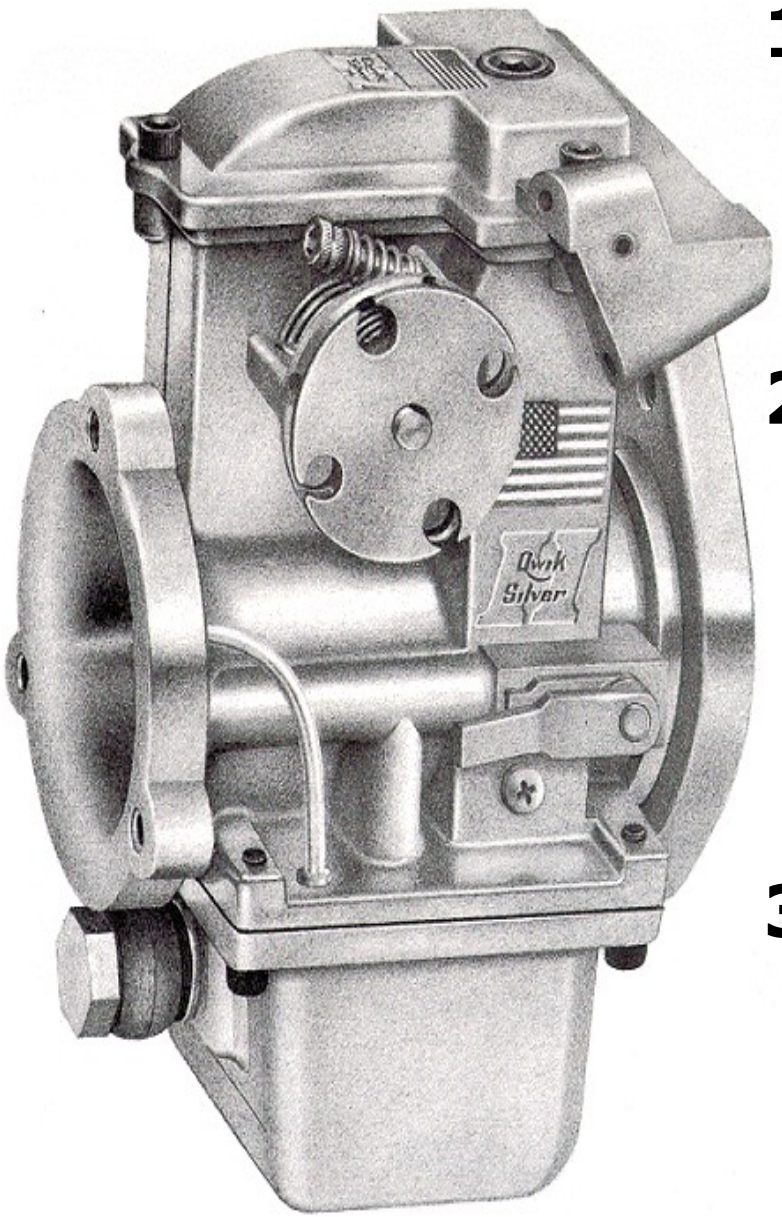
(Review, continued)

C. Carburetor Types
   1. Fixed venturi
      a. Butterfly throttle
      b. No slide
   2. Mechanical slide
      a. Mechanically controlled slide type throttle
      b. Slide has cutaway
   3. Constant velocity
      a. Butterfly throttle
      b. Vacuum controlled slide
      c. Slide has no cutaway
      d. Rubber diaphragm or metal piston
      e. Engine-controlled discharge
      f. Superior throttle response
      g. Lower exhaust emissions



(Review, continued)

D. Supplemental Circuits



1. Accelerator pump
   a. Prevents leanness on acceleration
   b. One-shot fuel pump
   c. Controlled by throttle linkage
2. Air cut valve
   a. Prevents afterburn on deceleration
   b. Plumbed into idle air bleed
   c. Associated with emissions-spec idle jetting
   d. Controlled by manifold press.
3. Powerjet
   a. Post-main circuit
   b. Controlled by pressure difference at air filter side
   c. Or by rpm data from ignition module

(Review, continued)

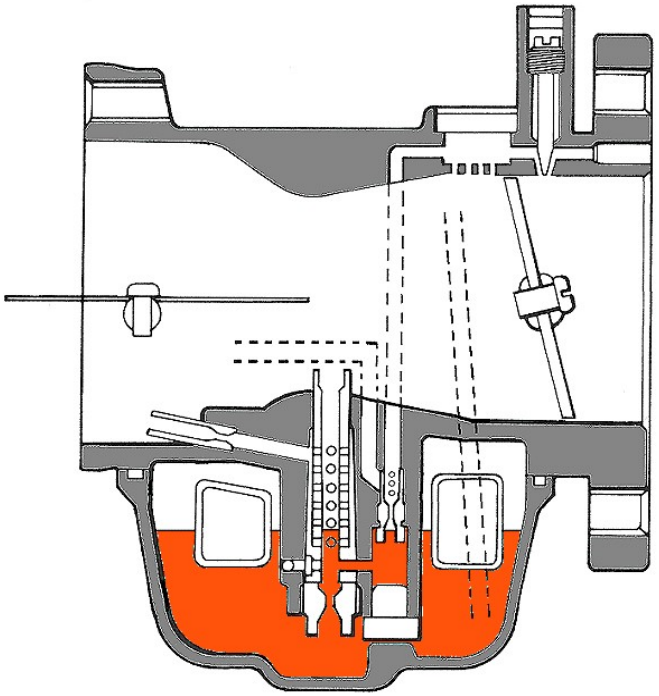
E. (Tunable) Circuit Ranges

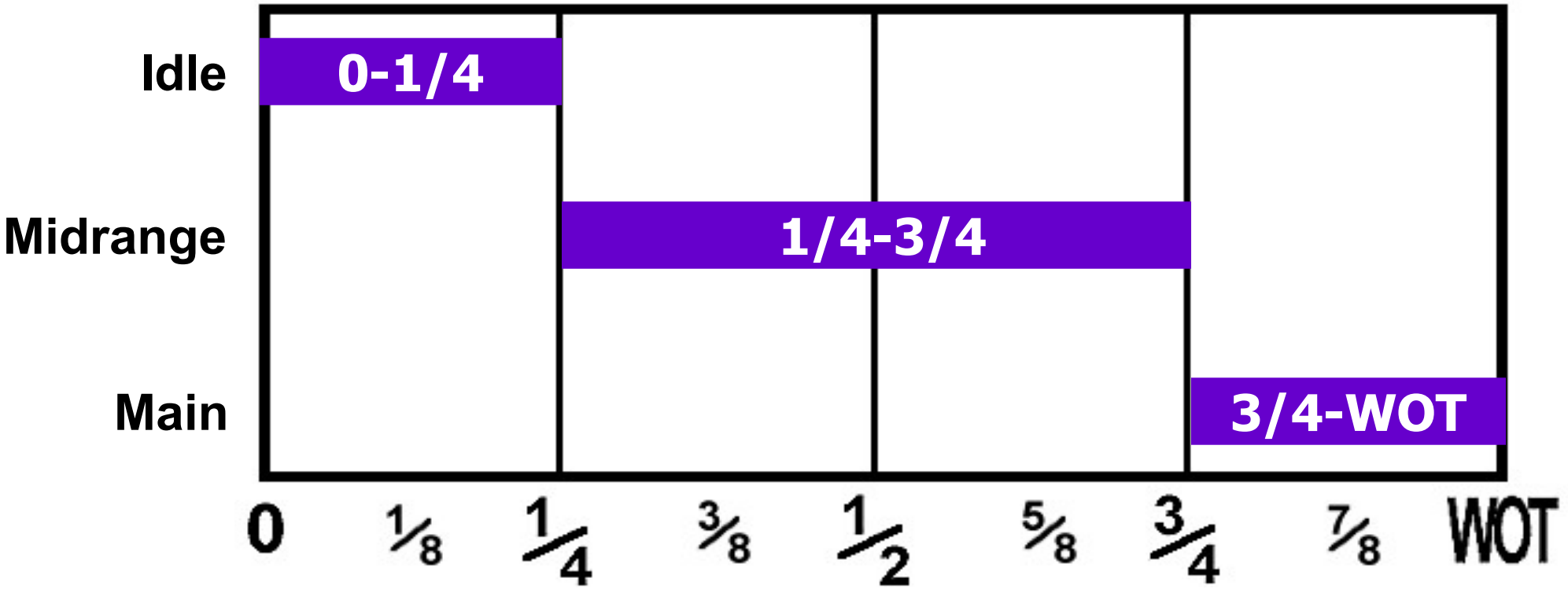
1. Fixed venturi carb

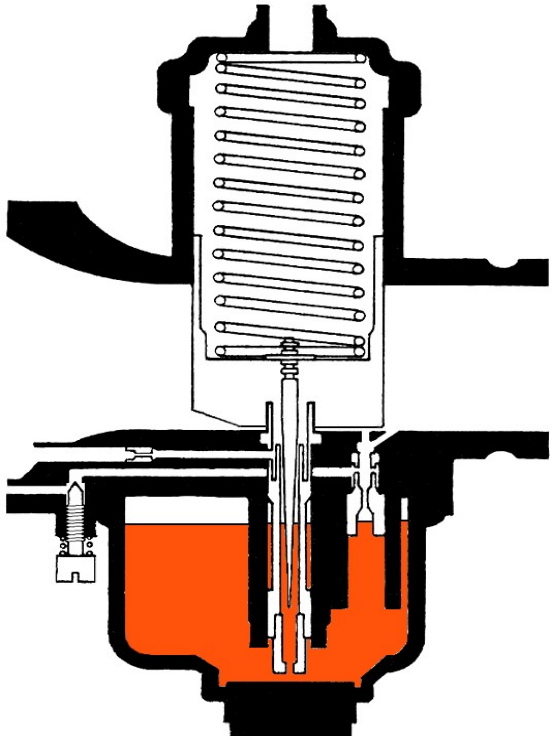
a. Idle (pilot, slow)

b. Midrange

c. Main

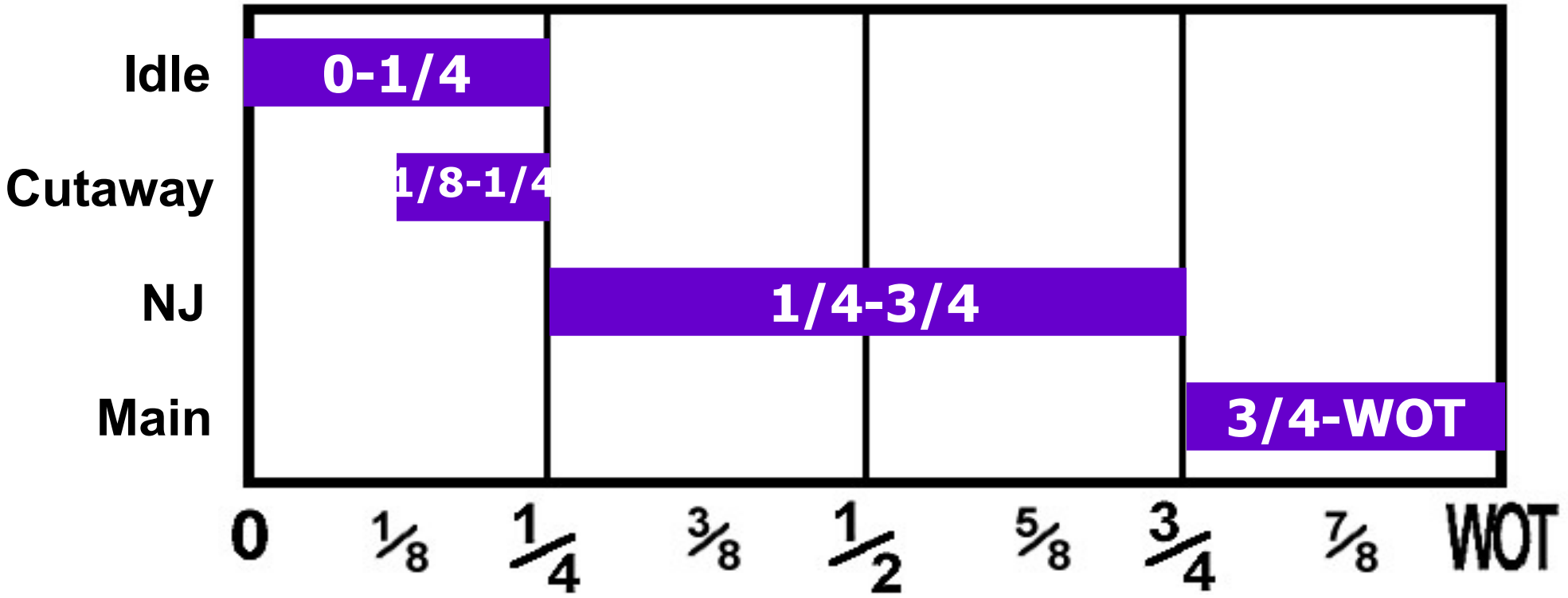






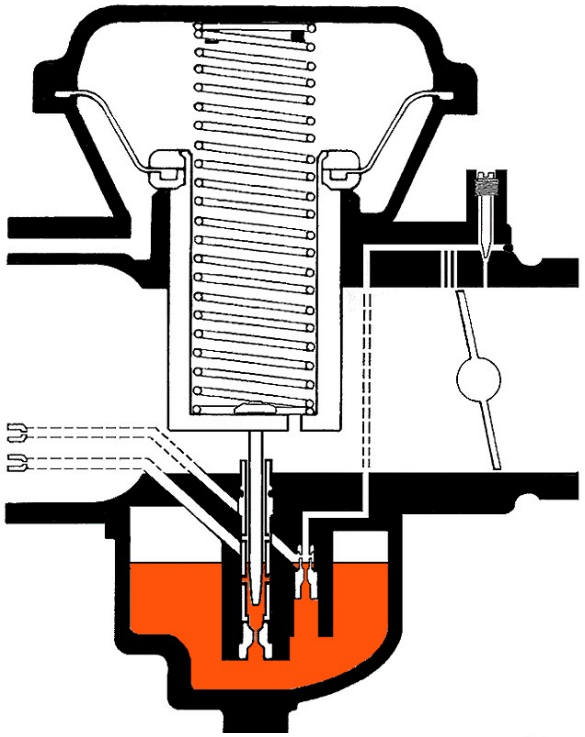
(Circuits, continued)

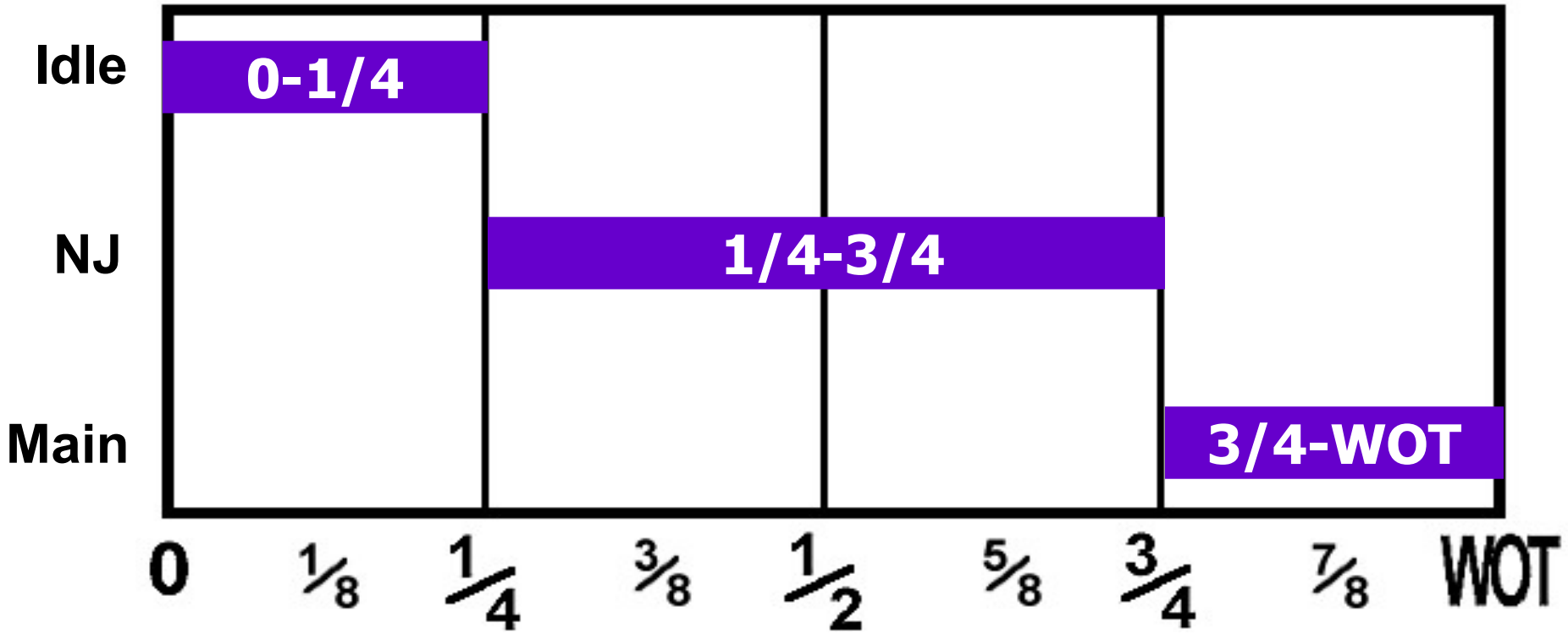
2. Mechanical slide carb
   a. Idle (pilot, slow)
   b. Needle jet/JN
   c. Slide cutaway
   d. Main

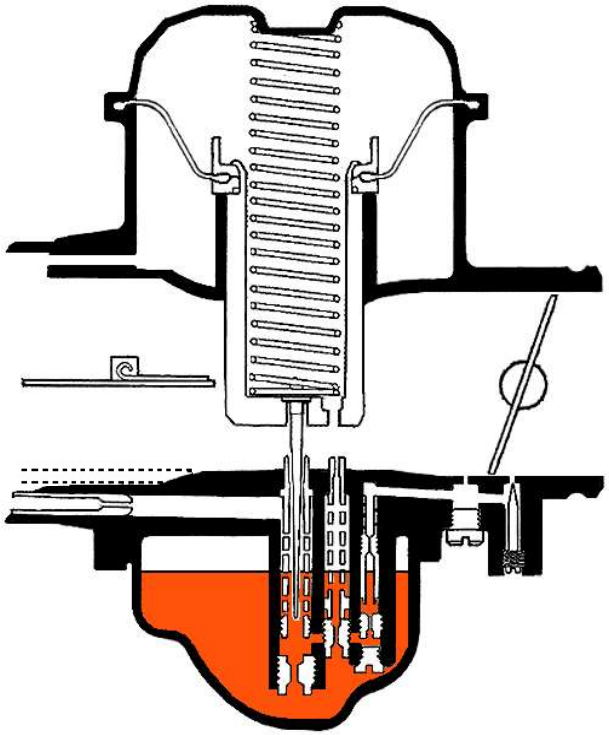


(Circuits, continued)

3. 2-jet constant velocity carb
   a. Idle (pilot, slow)
   b. Needle jet/JN
   c. Main

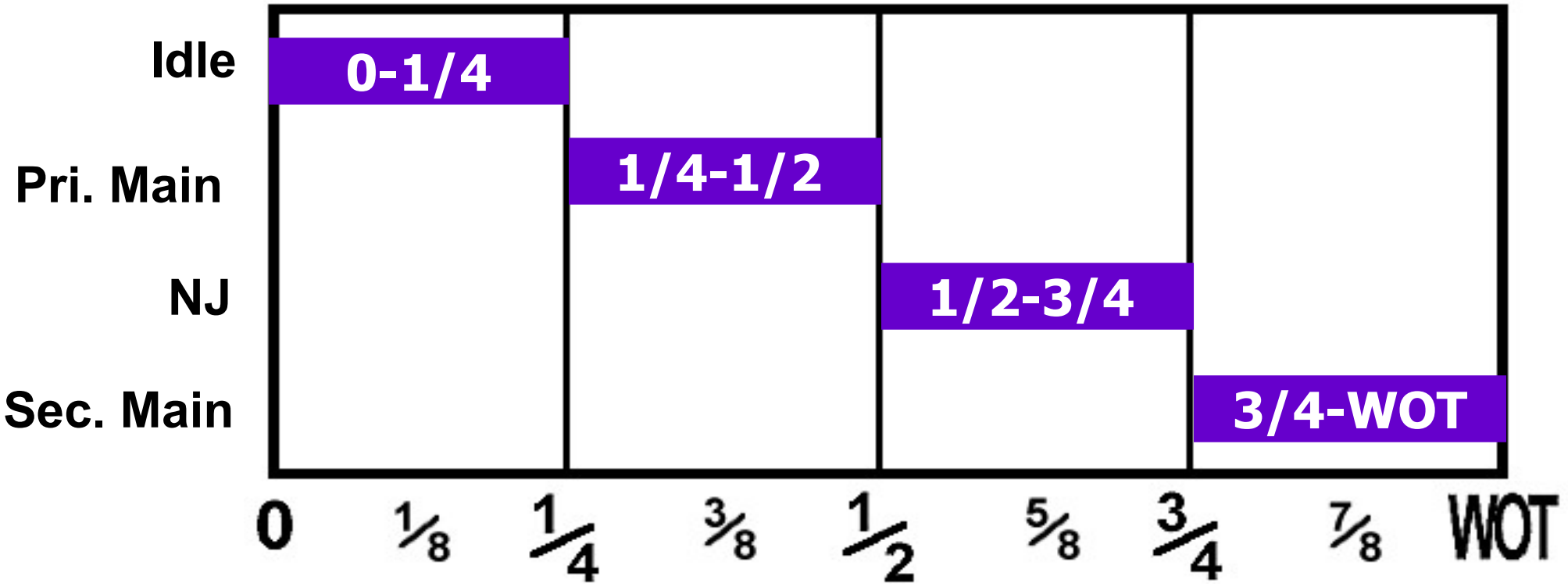






(Circuits, continued)

4. 3-jet constant velocity carb
   a. Idle (pilot, slow)
   b. Primary main
   c. Needle jet/JN
   d. Secondary main



Fuel Injection Overview

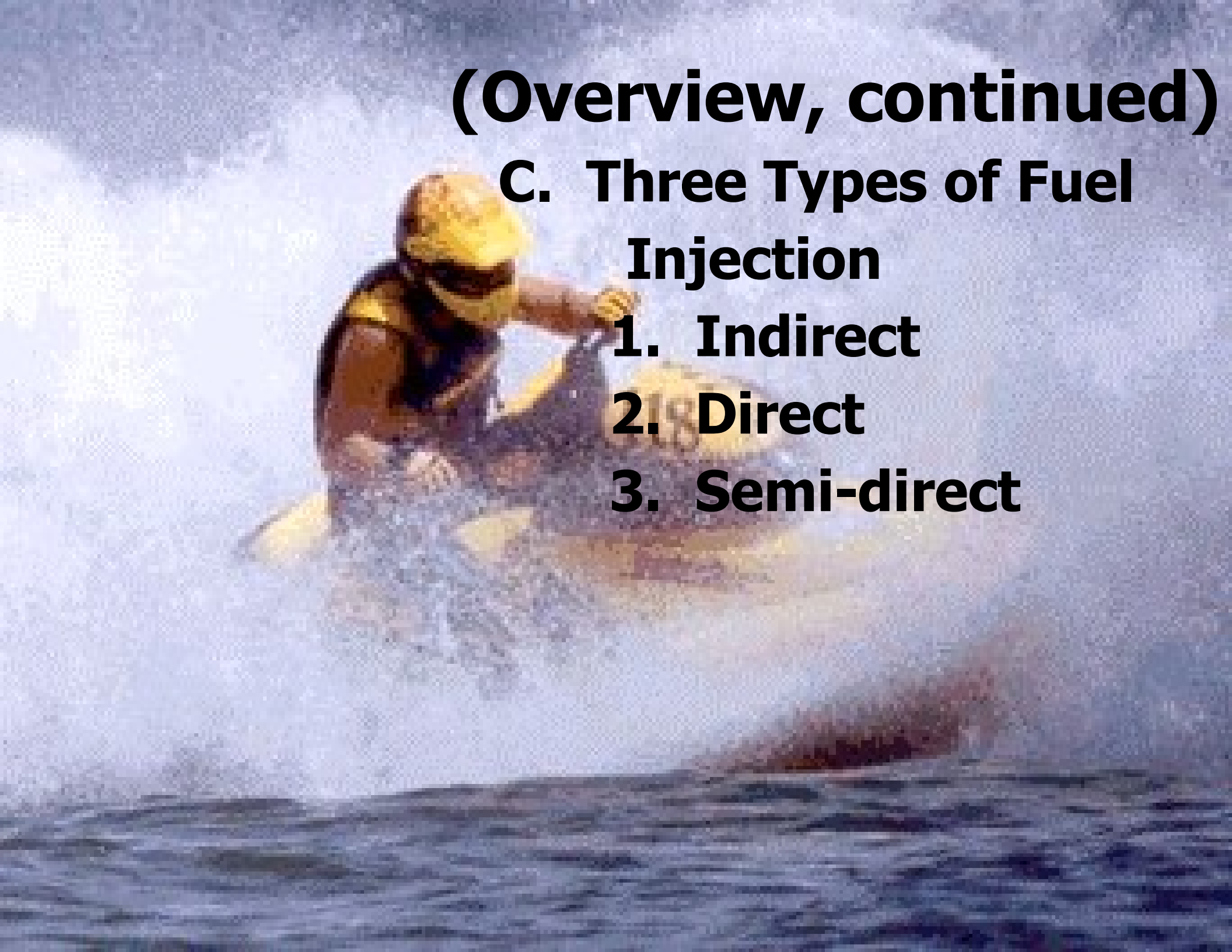
A. Introduction

1. What
2. Why
3. Where

(Overview, continued)

B. Basic Fuel Injection

1. Injectors
2. ECU
3. Sensors
4. Throttle body
5. Closed vs. open loop



(Overview, continued)

C. Three Types of Fuel Injection

1. Indirect
2. Direct
3. Semi-direct

Fuel Injection

I. Introduction

A. What

1. Fuel system that is electronically
   a. Metered,
   b. Timed,
   c. And, delivered
2. Replaces carburetor

(Introduction, continued)

B. Why

1. Fuel discharge not dependent on engine's pressure differences
   a. Carburetor's "wick effect" limited as to the number of variables it can compensate for
   b. Called "injection" to emphasize fact that control is from outside the engine
2. "Smart" (teachable) fuel delivery
3. Increasing emissions regulations

(Introduction, continued)

C. Where

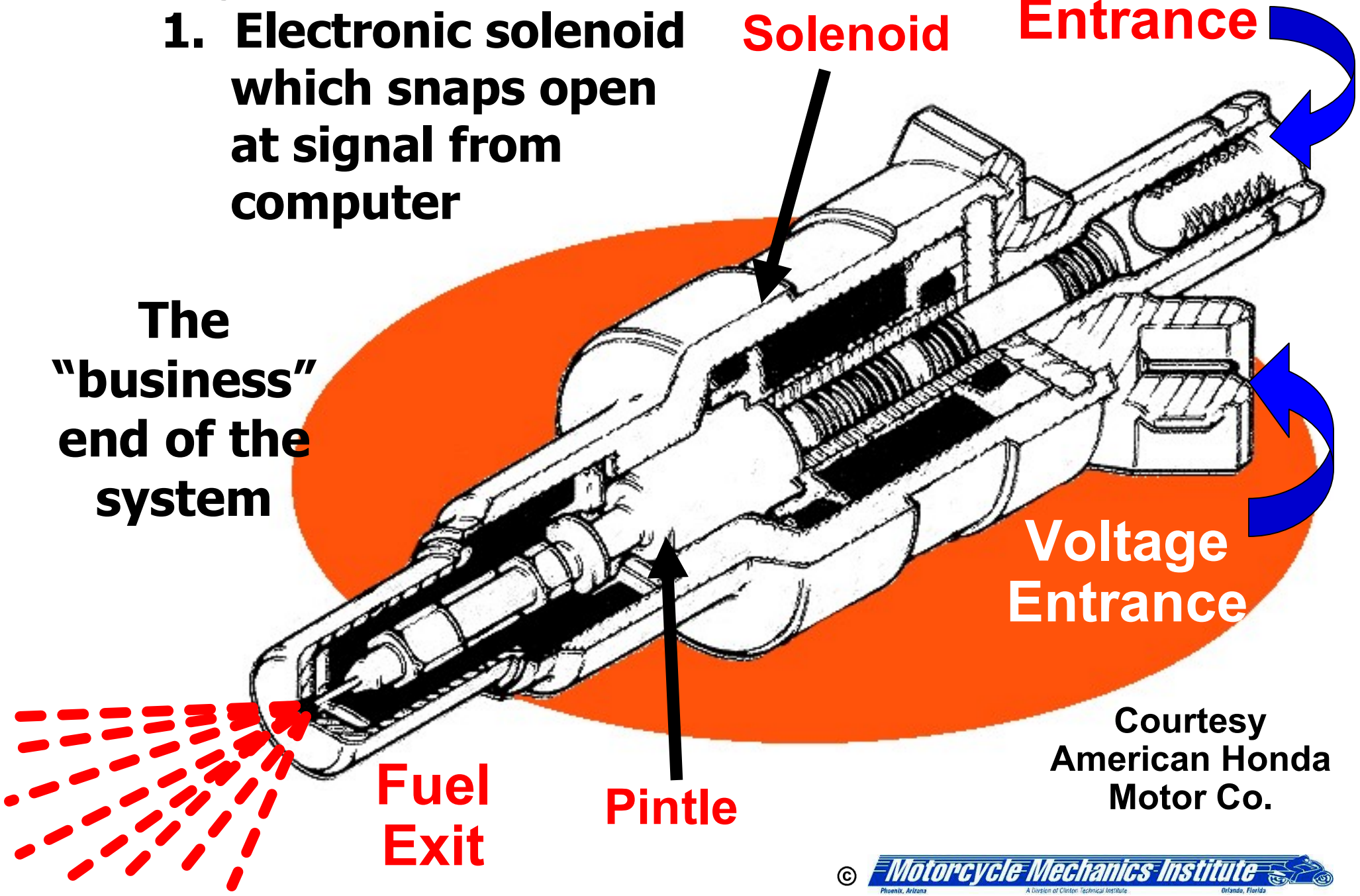
1. Motorcycles
2. Personal watercraft
3. Marine engines

II. Basic Fuel Injection

A. Injector

1. Electronic solenoid which snaps open at signal from computer

The "business" end of the system

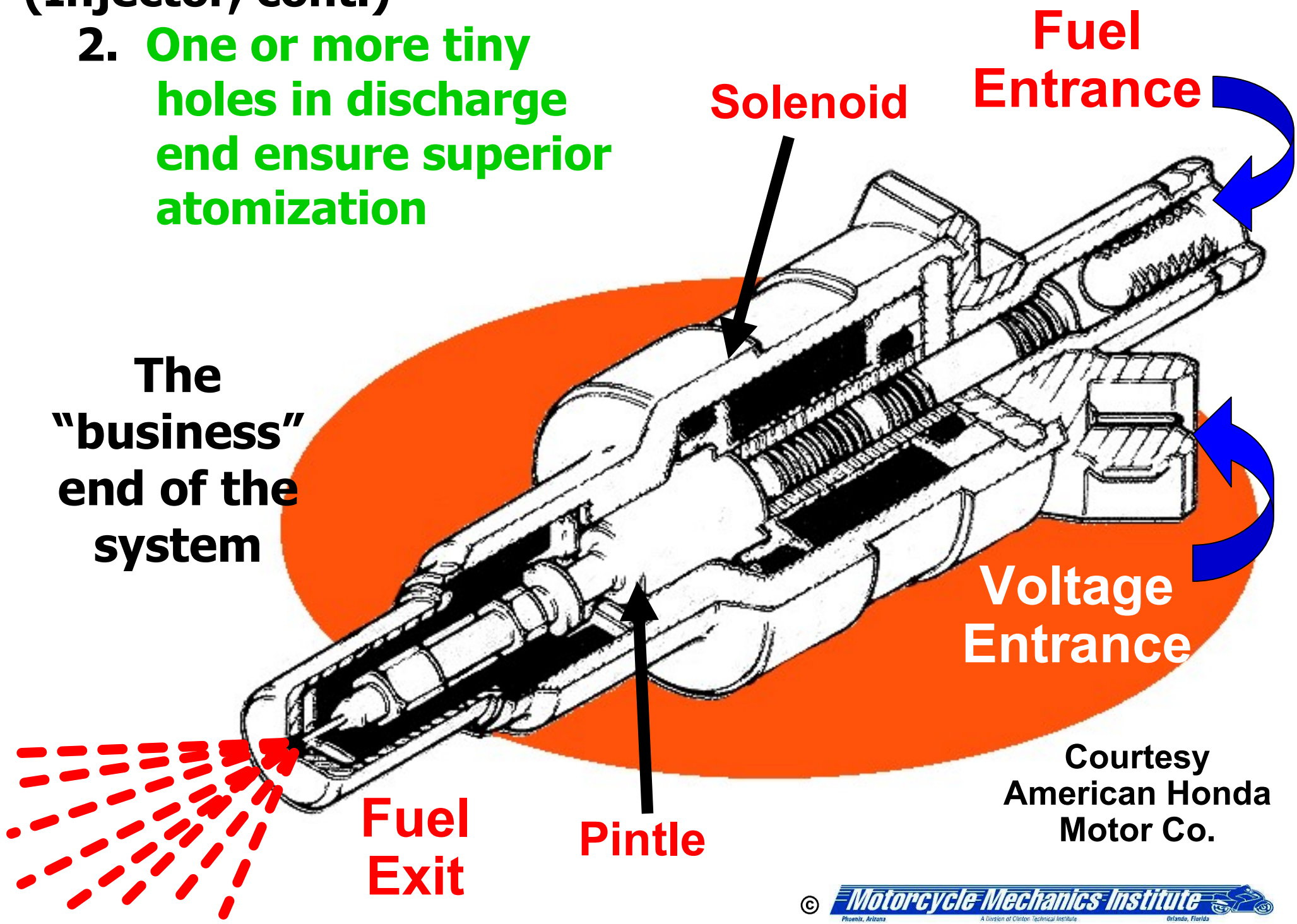


Courtesy American Honda Motor Co.

(Injector, cont.)

2. One or more tiny holes in discharge end ensure superior atomization

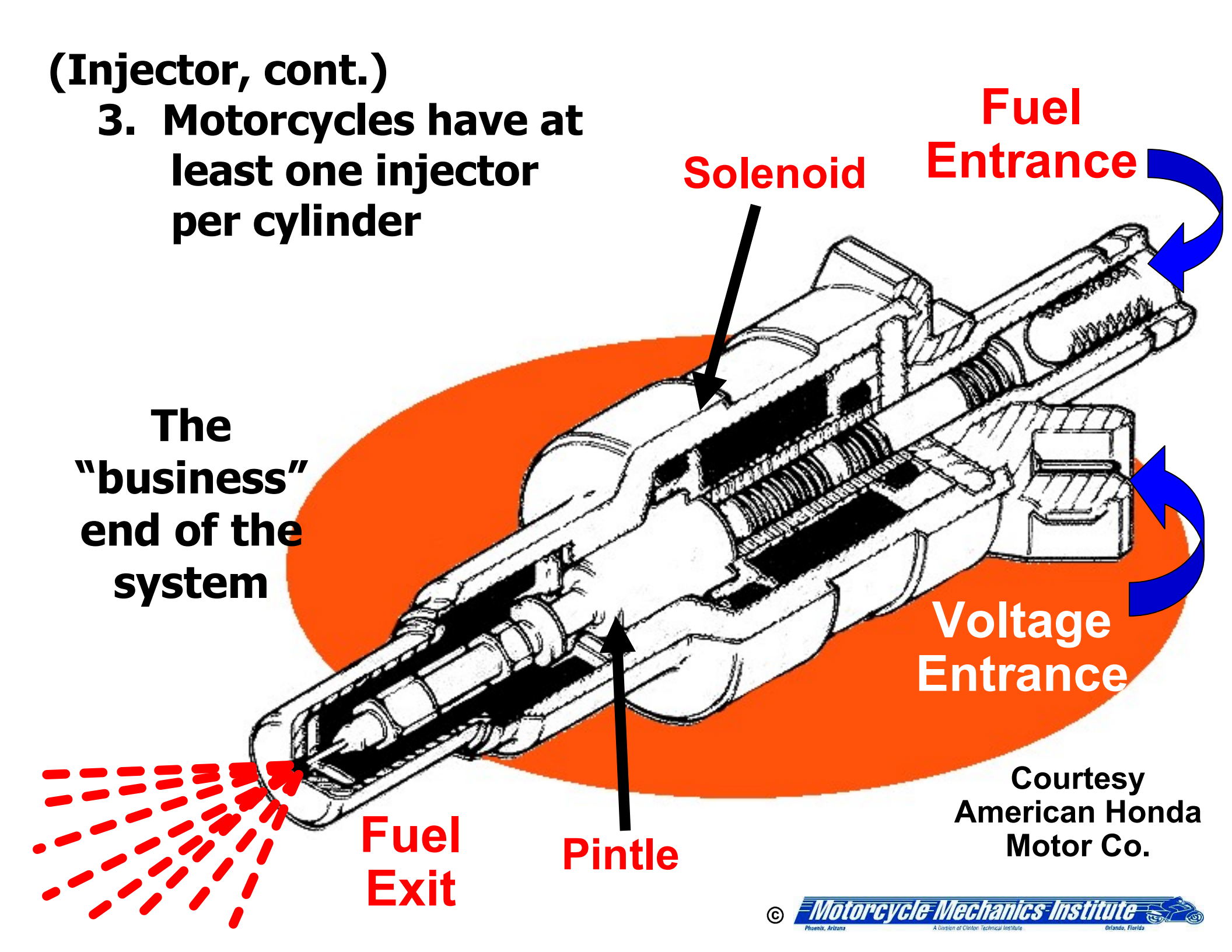
The "business" end of the system



Courtesy American Honda Motor Co.

(Injector, cont.)

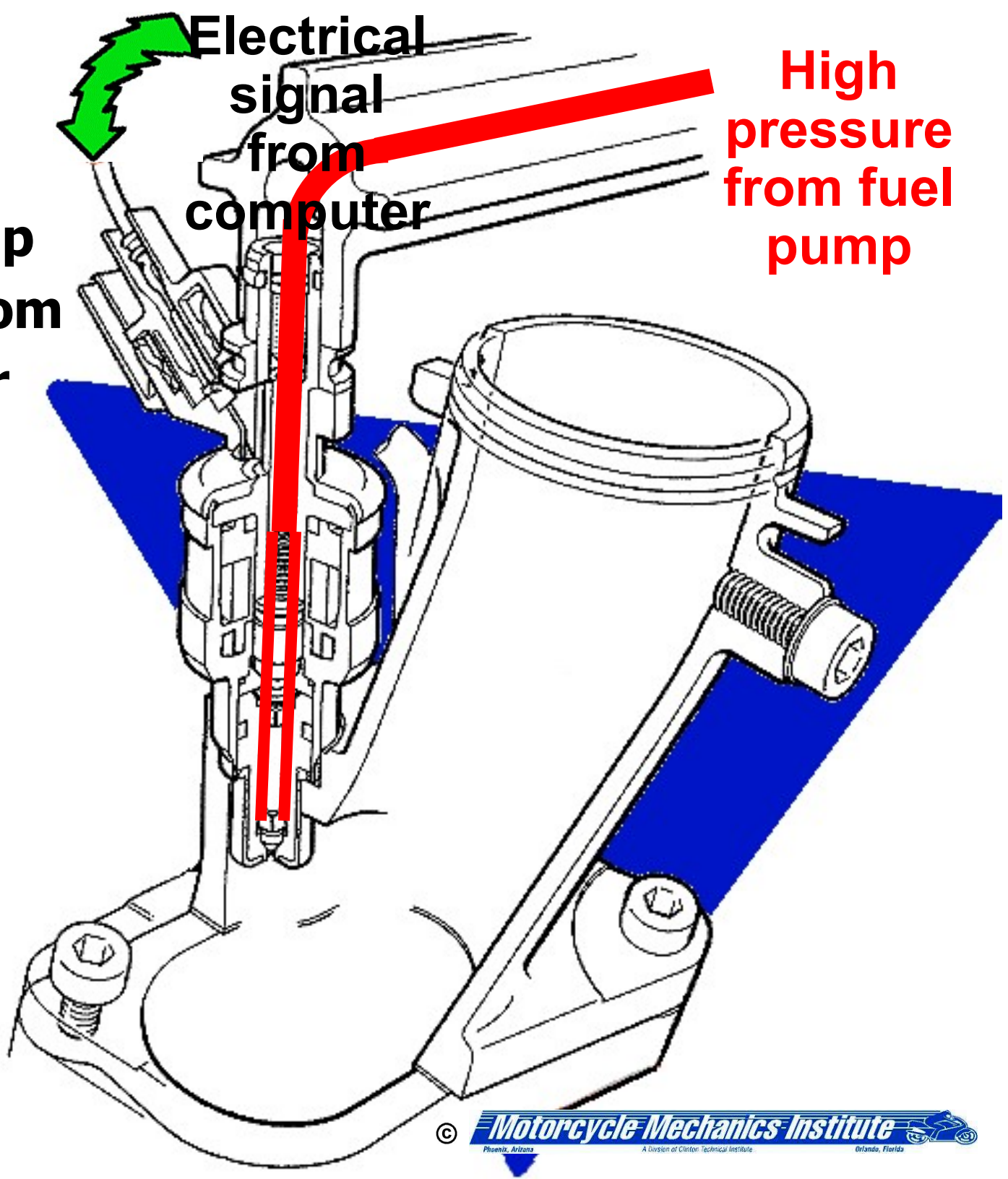
3. Motorcycles have at least one injector per cylinder



Courtesy American Honda Motor Co.

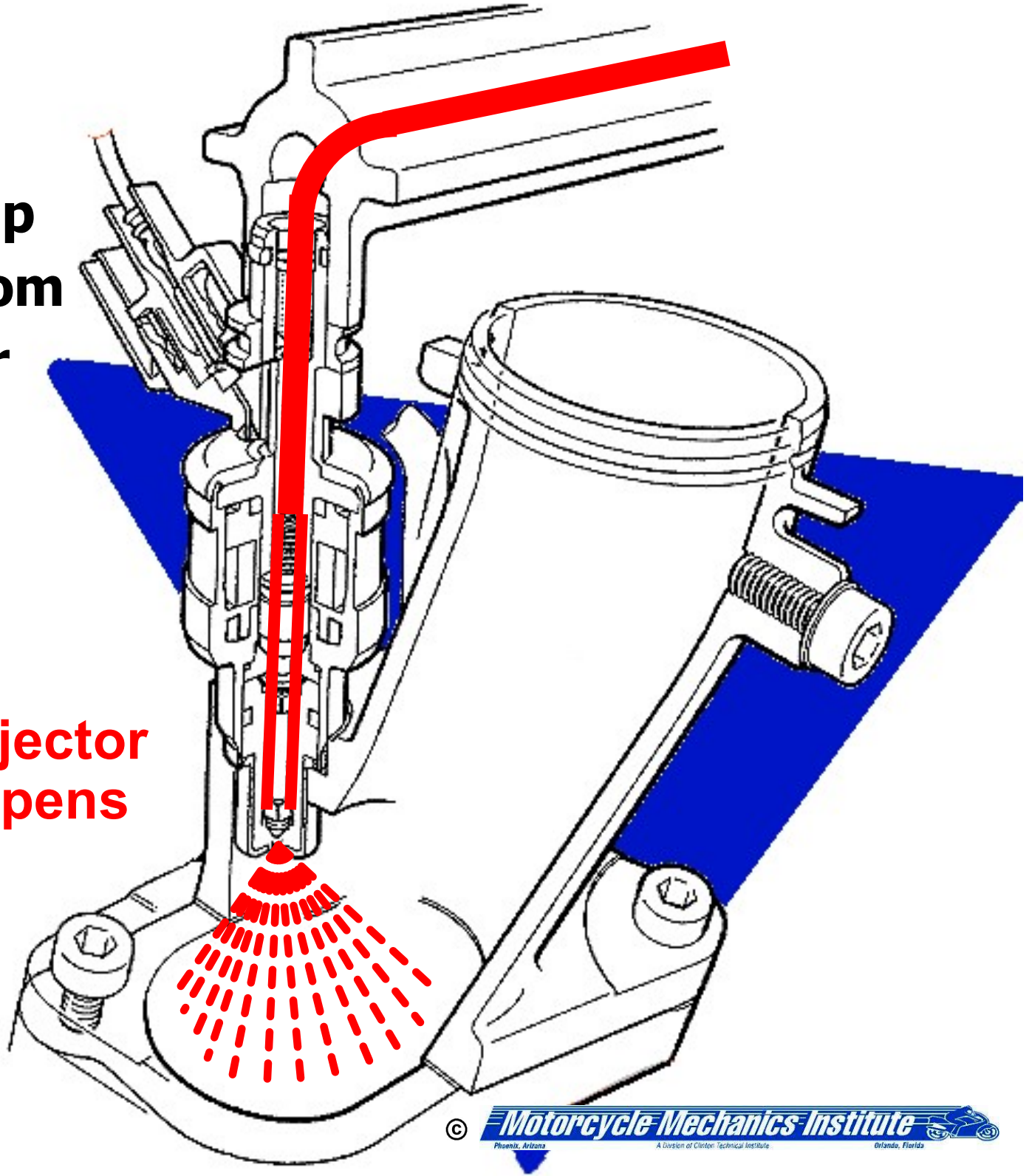
(Injector, cont.)

4. Function
   a. Fuel pump
   b. Signal from computer
   c. Solenoid opens



(Injector, cont.)

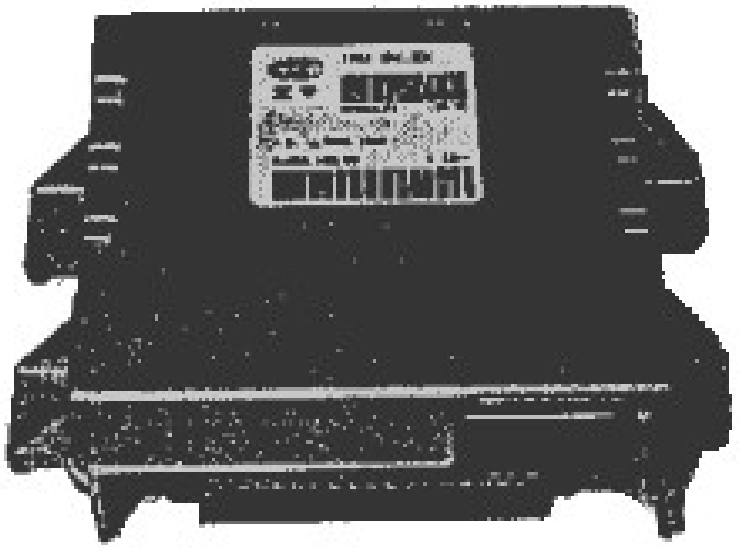
4. Function
   a. Fuel pump
   b. Signal from computer
   c. Solenoid opens



(Basic Fuel Injection, cont.)

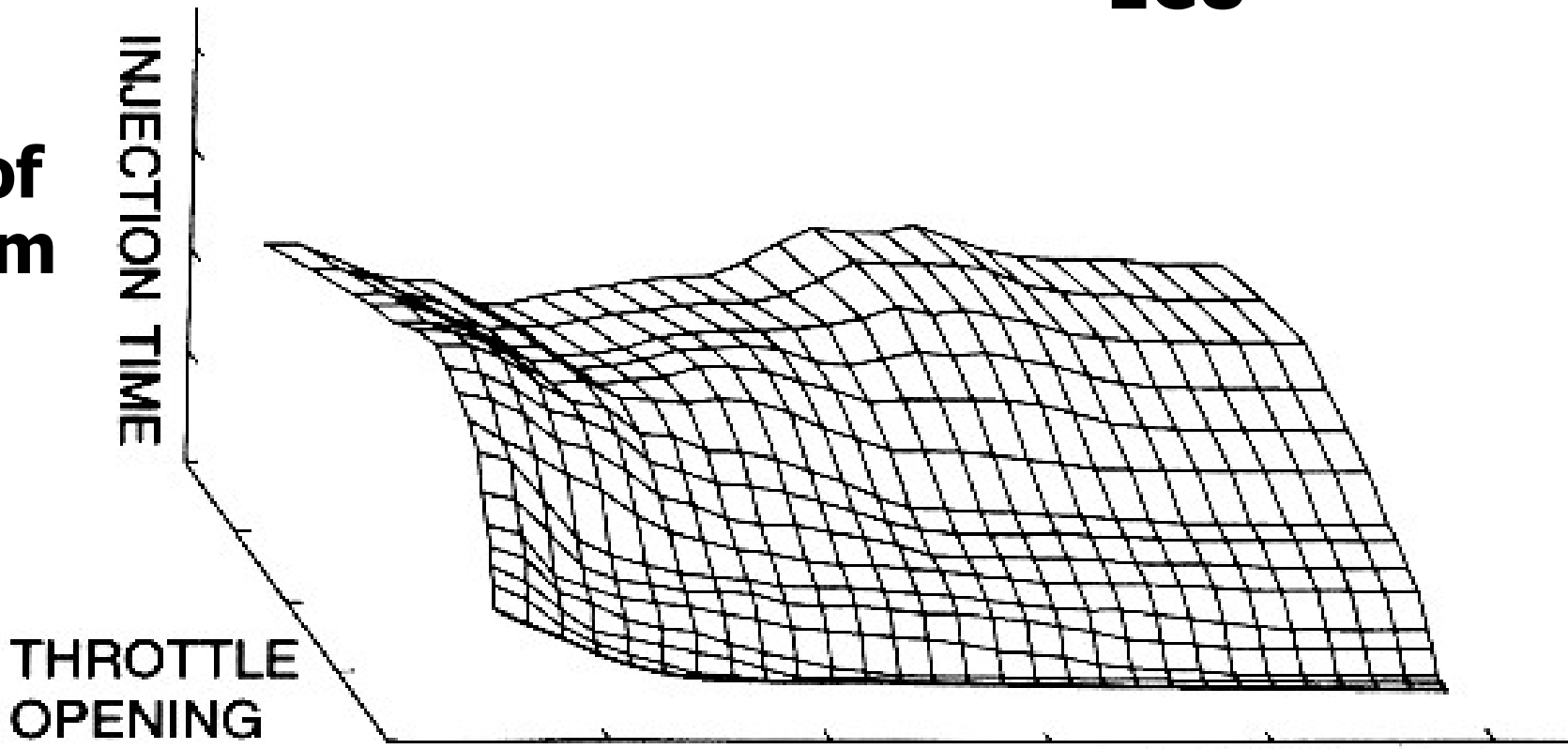
B. Computer (Electronic Control Unit, or "ECU")

1. Controls A/F ratio by selecting among several 3-dimensional mixture curves ("maps")



ECU

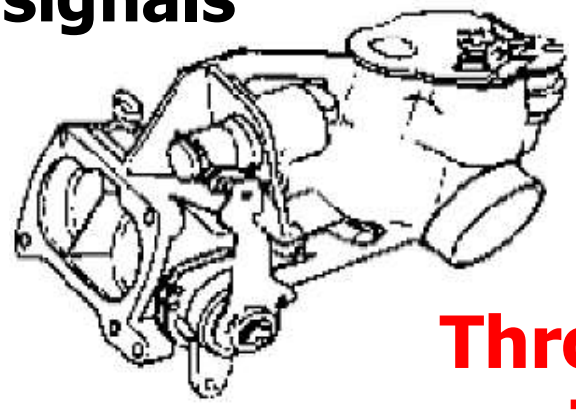
The "brains" of the system



(Basic Fuel Injection, cont.)

C. Sensors

1. Convert physical conditions into elect. signals



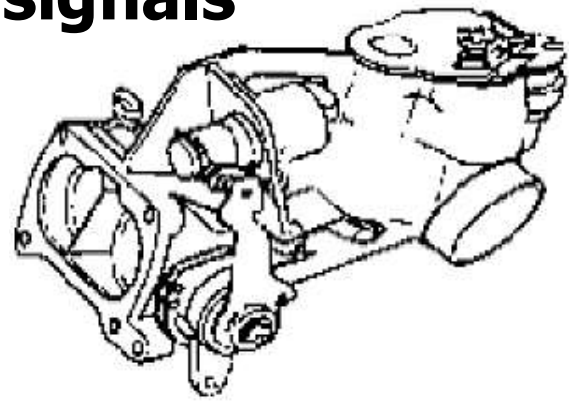
Throttle position

The "eyes and ears"of the system

(Basic Fuel Injection, cont.)

C. Sensors

1. Convert physical conditions into elect. signals



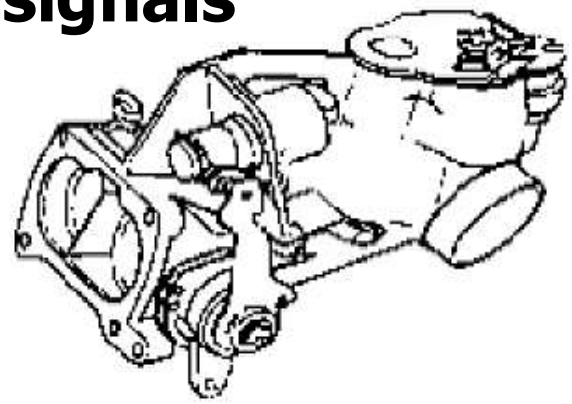
The "eyes and ears"of the system

Camshaft position

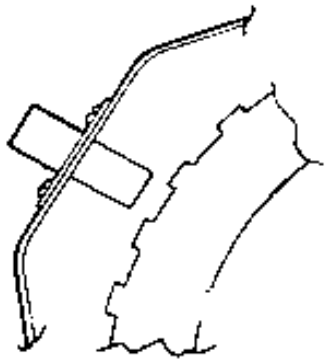
(Basic Fuel Injection, cont.)

C. Sensors

1. Convert physical conditions into elect. signals



The "eyes and ears"of the system

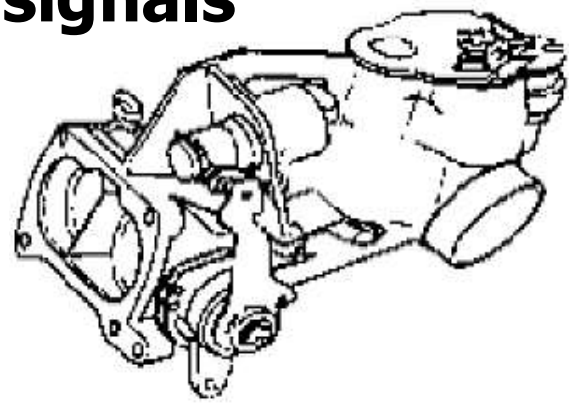


Crankshaft position

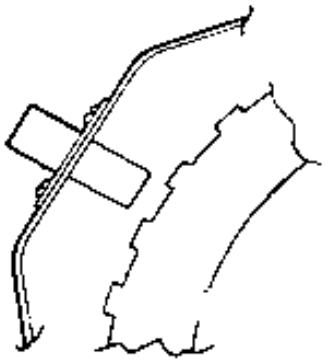
(Basic Fuel Injection, cont.)

C. Sensors

1. Convert physical conditions into elect. signals



The "eyes and ears"of the system

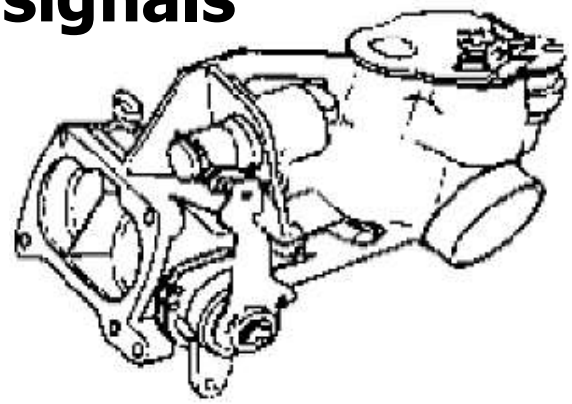


Intake Air Temp

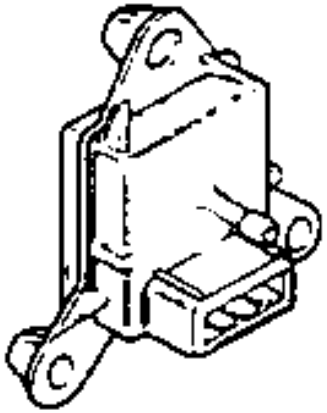
(Basic Fuel Injection, cont.)

C. Sensors

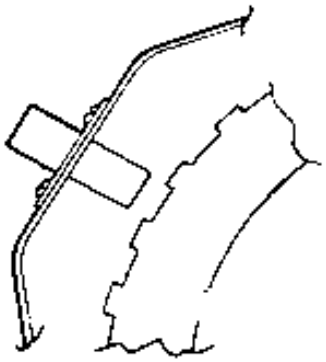
1. Convert physical conditions into elect. signals



Barometric Pressure



The "eyes and ears"of the system

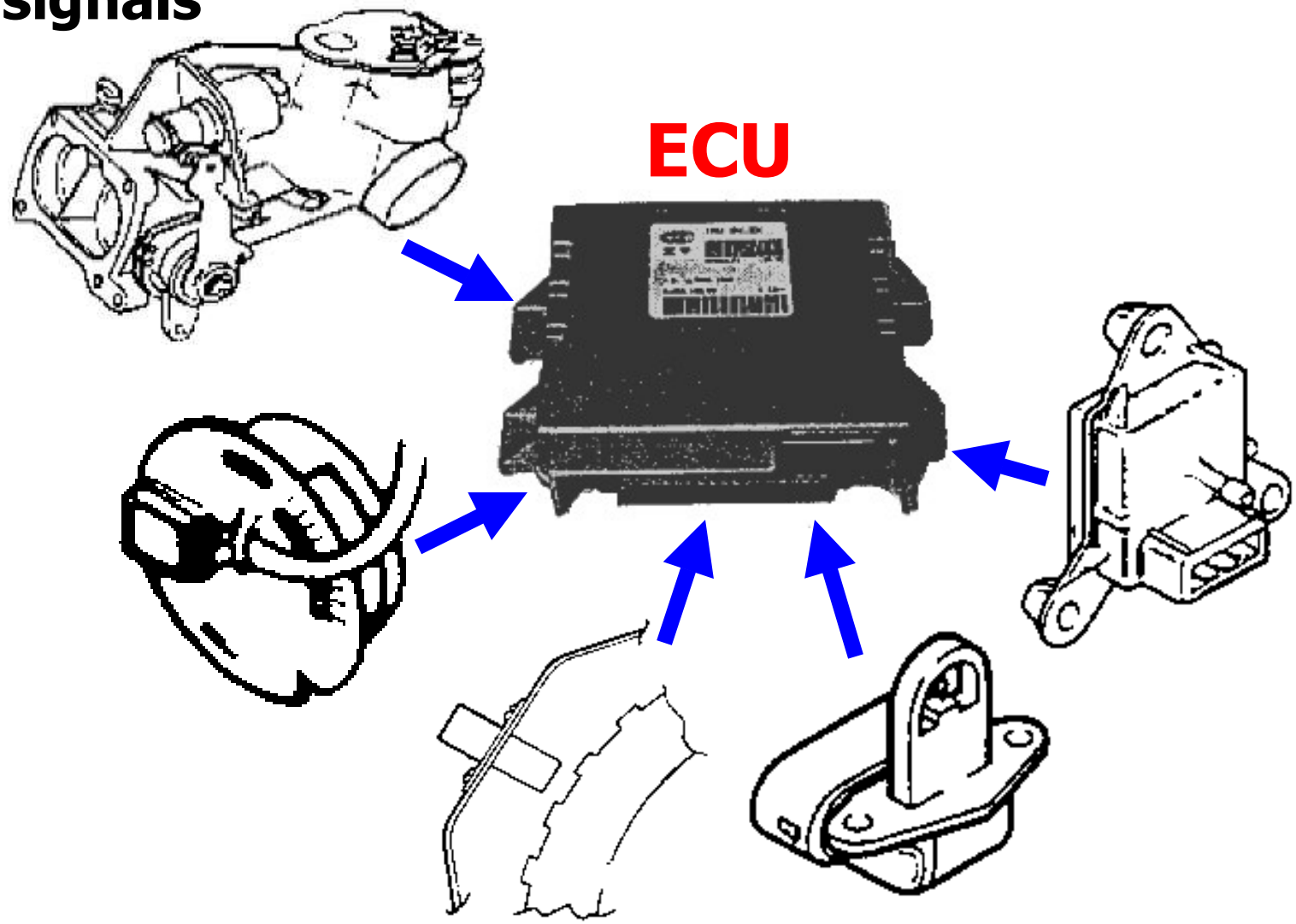


(Basic Fuel Injection, cont.)

C. Sensors

1. Convert physical conditions into elect. signals

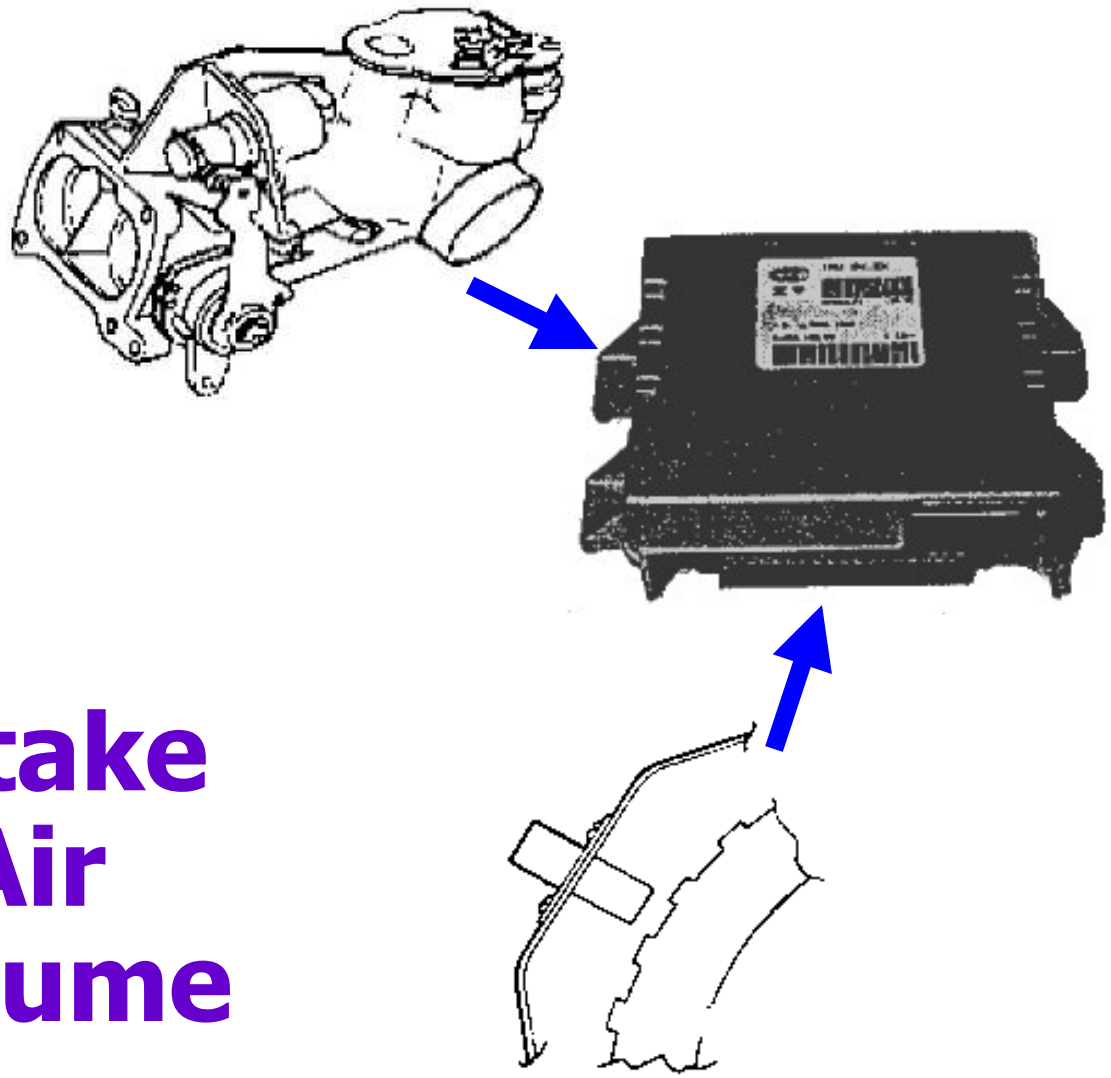
The "eyes and ears"of the system



(Sensors, cont.)

2. From the sensor input the ECU "knows" intake air makeup

Throttle Position + Rpm = Cylinder Air Volume

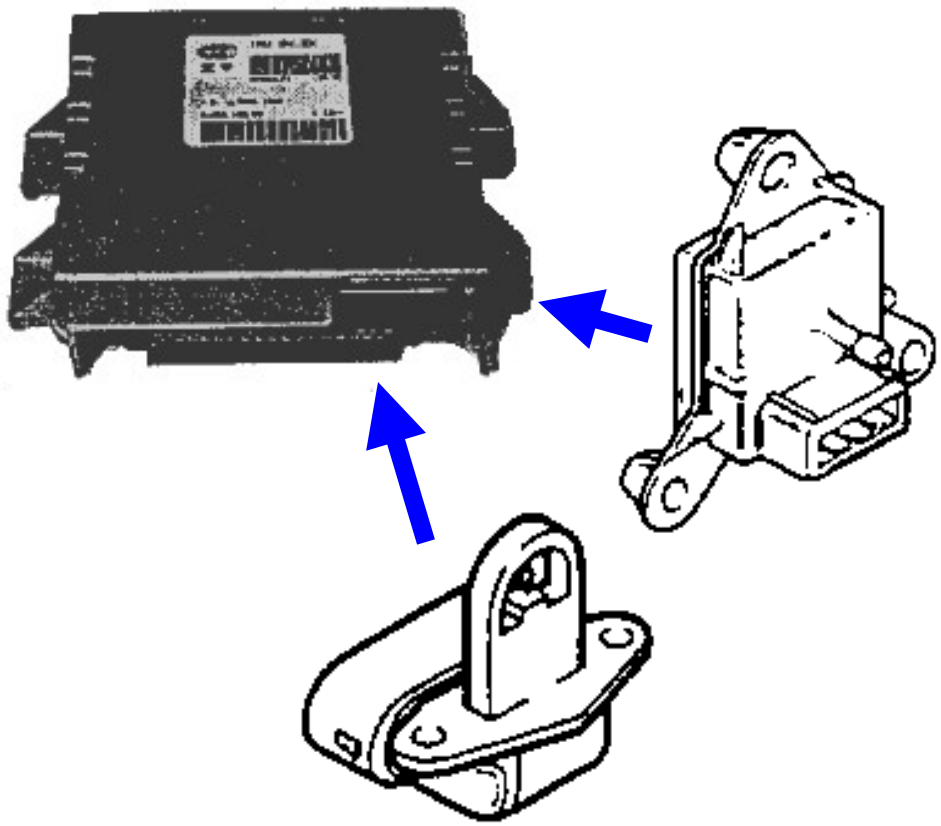


Intake Air Volume

(Sensors, cont.)

2. From the sensor input the ECU "knows" intake air makeup

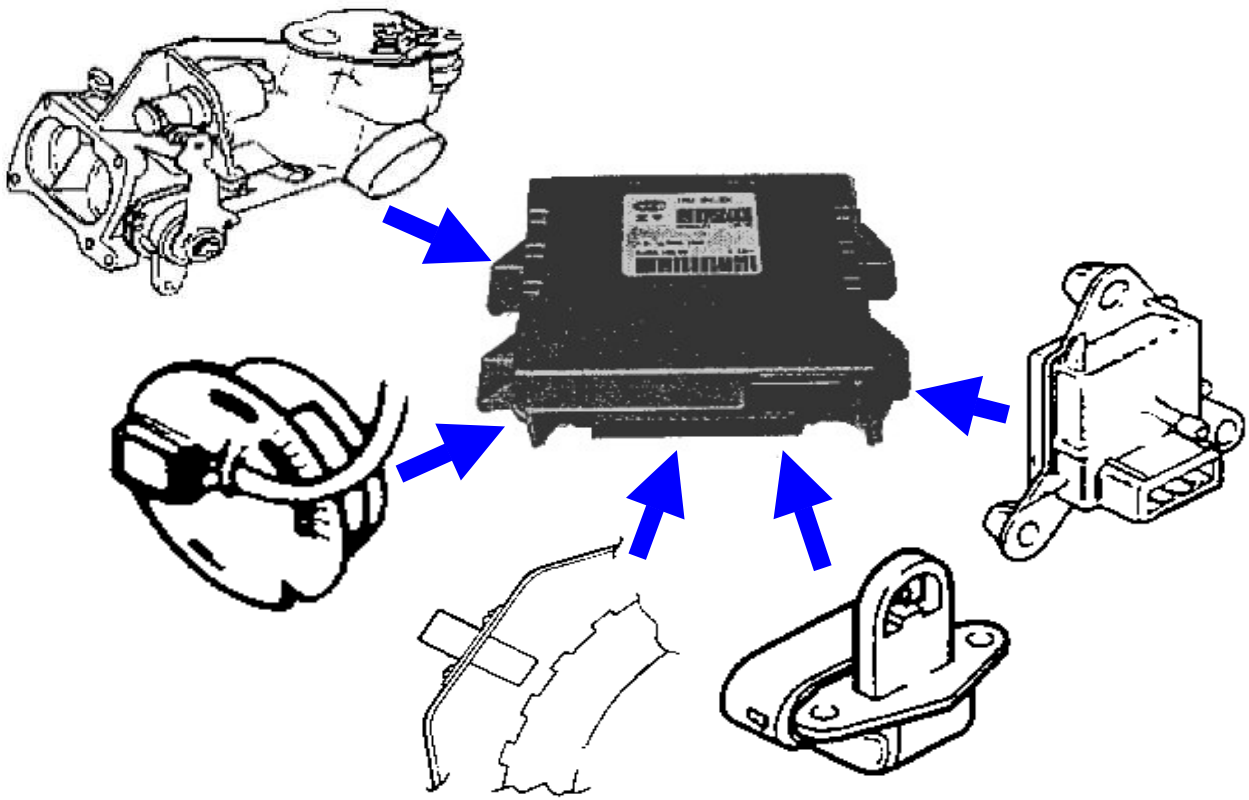
Intake Air Temp + Barometric Pressure = Cylinder Air Density



Intake Air Density

(Sensors, cont.)

3. From this input the ECU decides on a basic mixture ratio



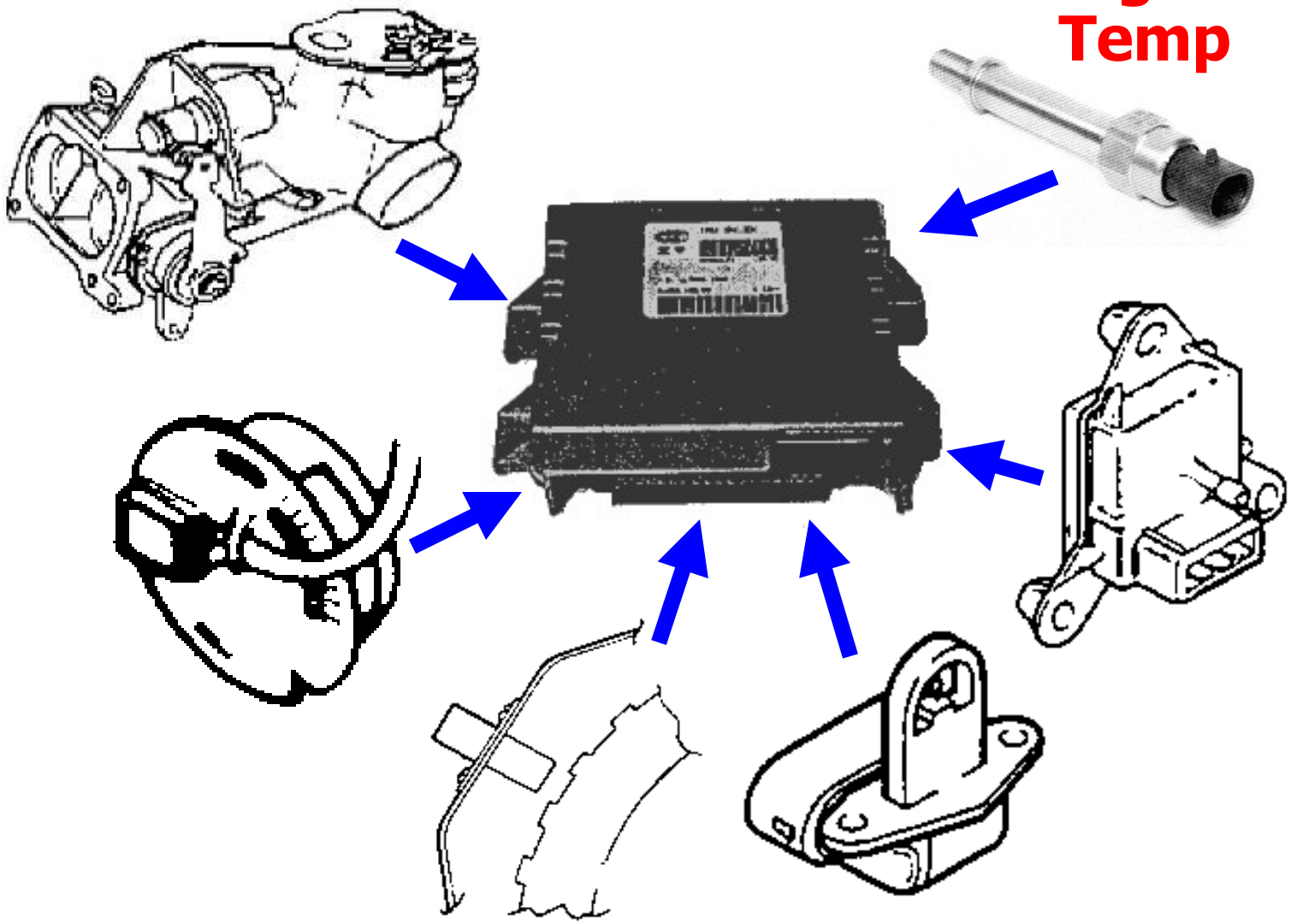
Throttle Position + Rpm = Cylinder Air Volume

Intake Air Temp + Barometric Pressure = Cylinder Air Density

Cylinder Air Volume + Cylinder Air Density = Basic Mixture

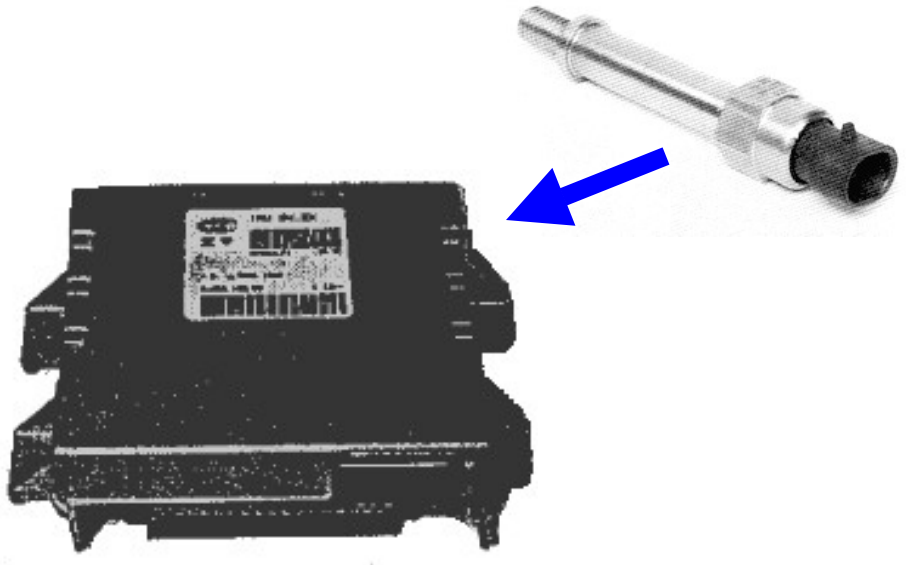
(Sensors, cont.)

4. A final check is then made of the engine temperature



(Sensors, cont.)

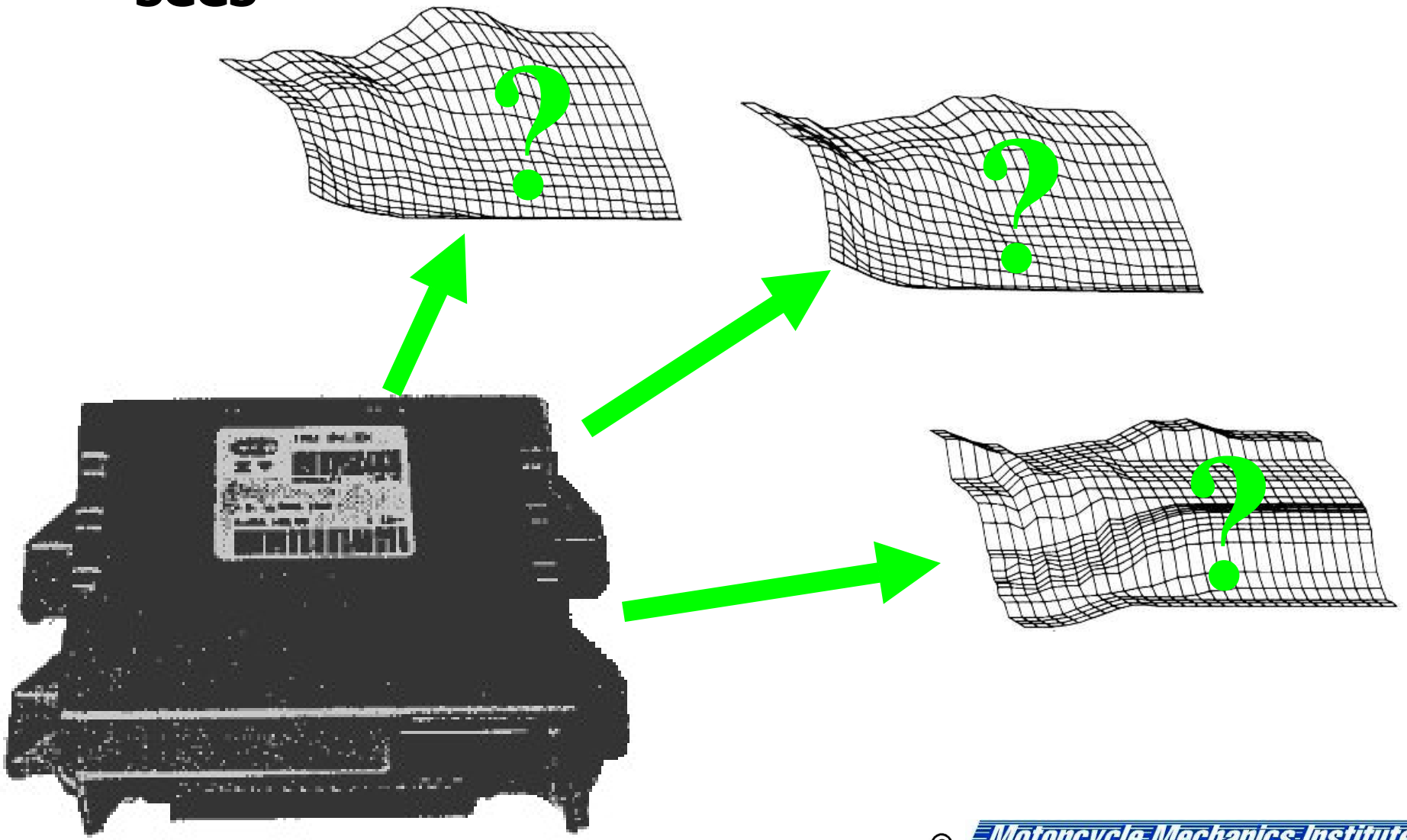
5. The mixture ratio is fine-tuned based on the temp data



Basic Mixture + [Engine Temp] = Final Mixture

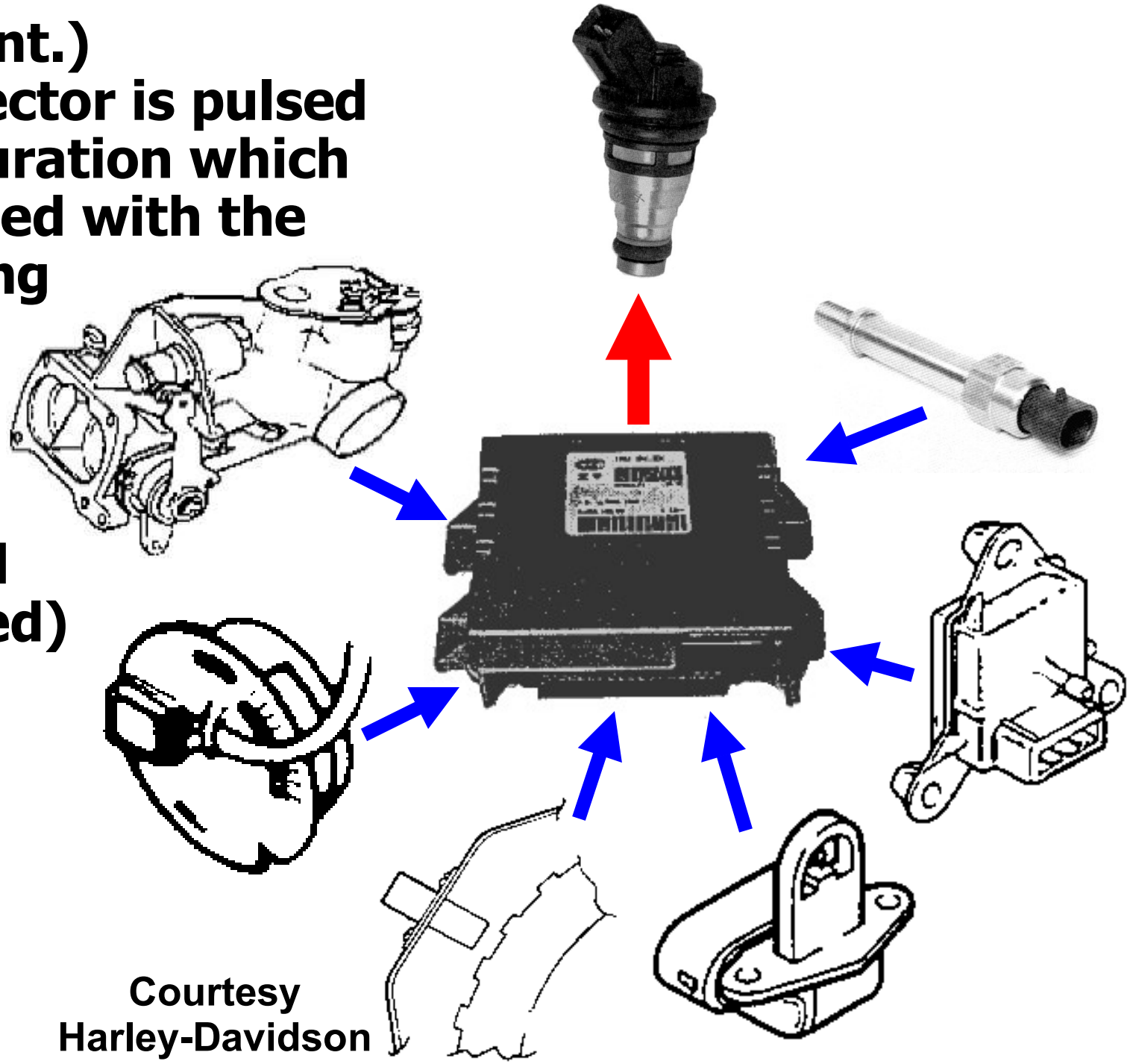
(Sensors, cont.)

6. The ECU chooses the map which most closely matches the "picture" it sees



(Sensors, cont.)

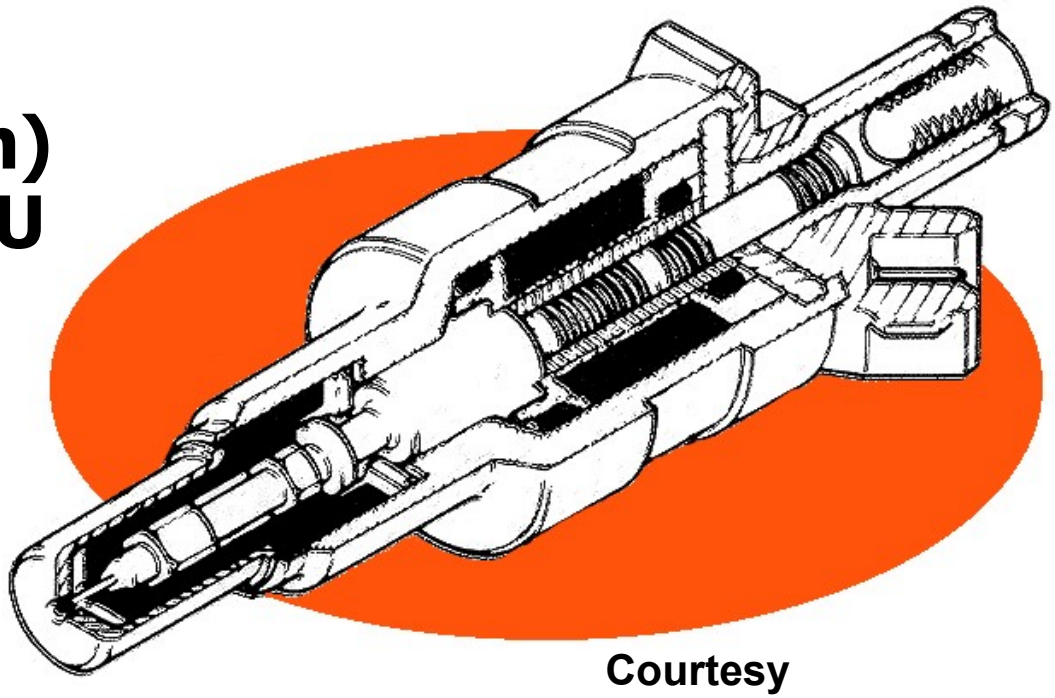
7. The injector is pulsed for a duration which combined with the incoming air gives the ECU-charted (mapped) ratio



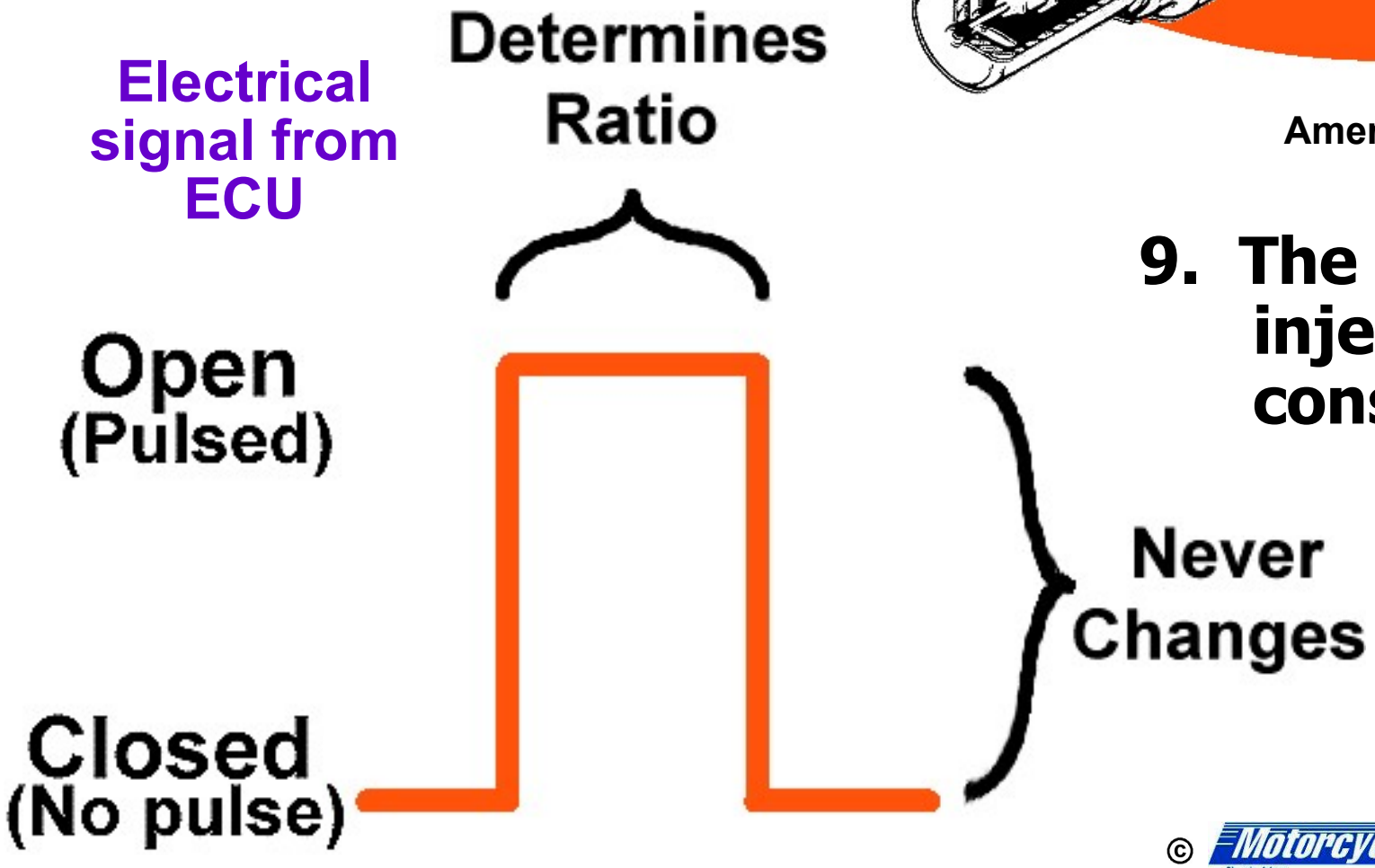
Courtesy
Harley-Davidson
Motor Co.

(Sensors, cont.)

8. Pulse duration (width) is the variable the ECU determines, which makes the mixture rich or lean



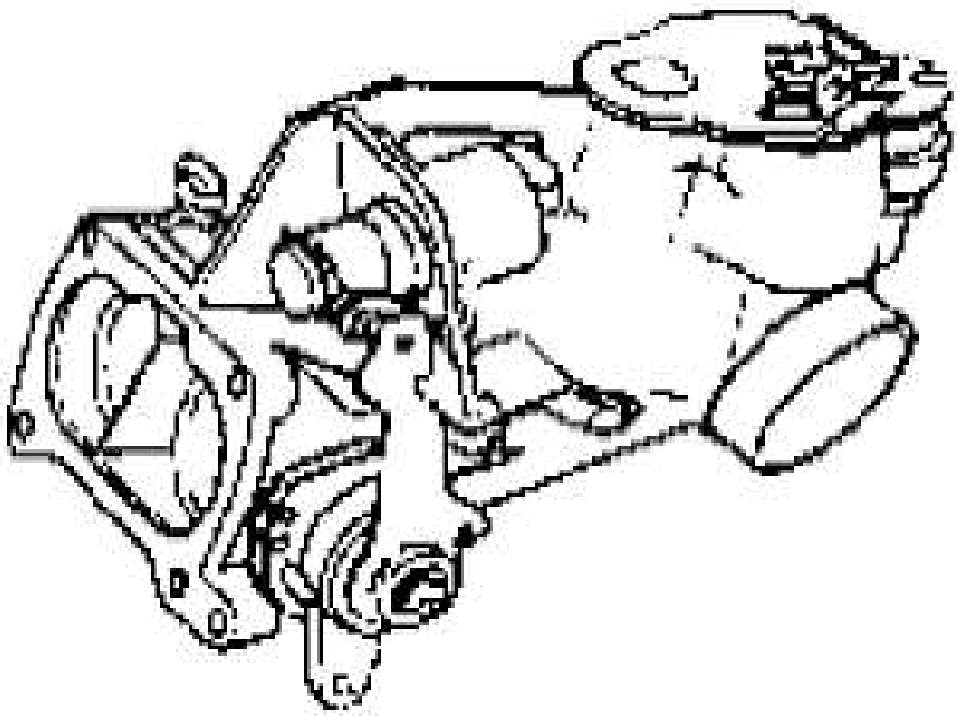
Courtesy
American Honda Motor Co.



9. The distance the injector opens is constant

(Basic Fuel Injection, cont.)

D. Throttle body
   1. Physical replace-ment for the carburetor
   2. Throttle butterflies
   3. Often houses some sensors also



Harley-Davidson 1340

Honda CBR929RR

(Basic Fuel Injection, cont.)

E. Closed vs. open loop

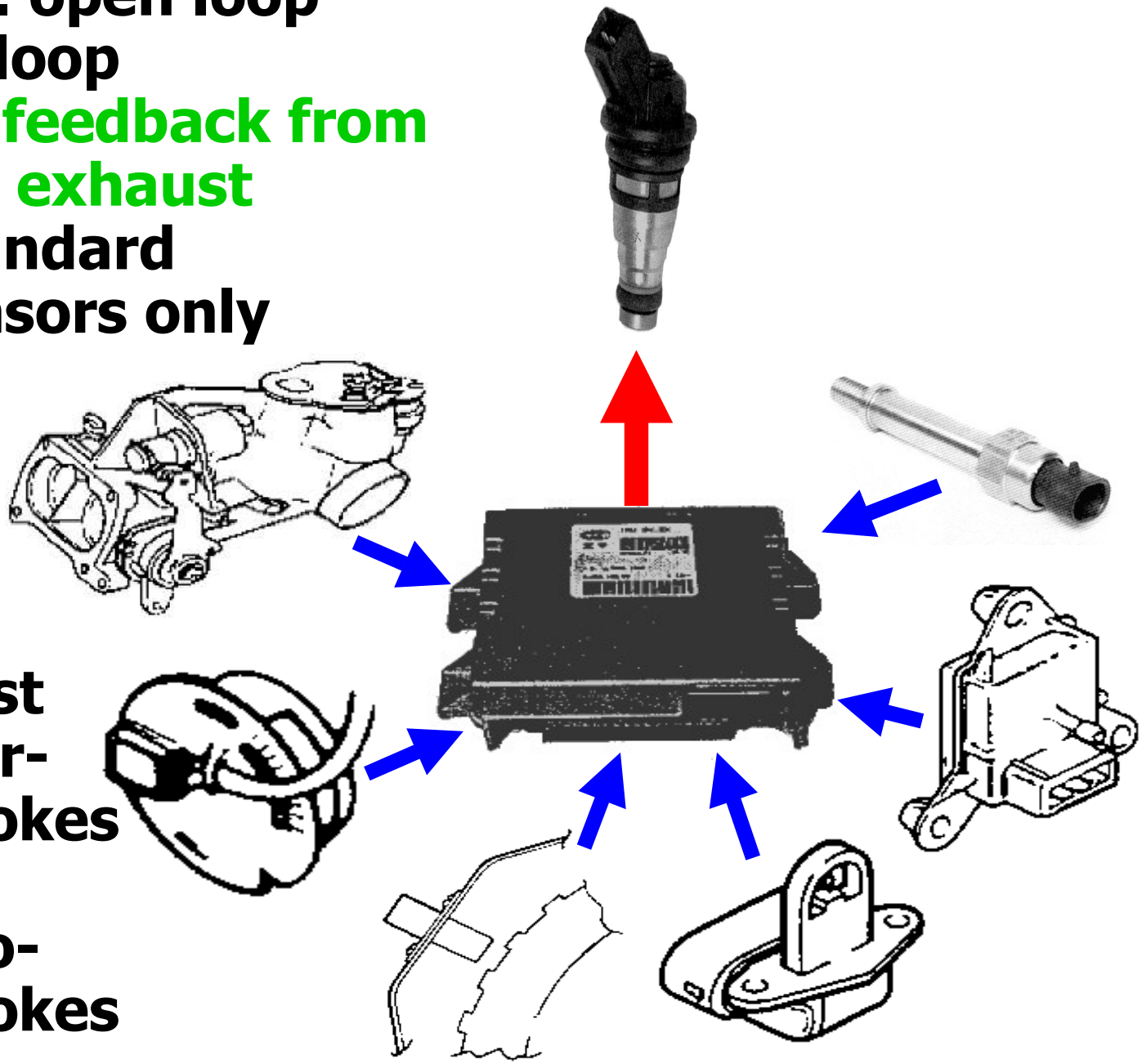
1. Open loop

a. No feedback from the exhaust

b. Standard sensors only

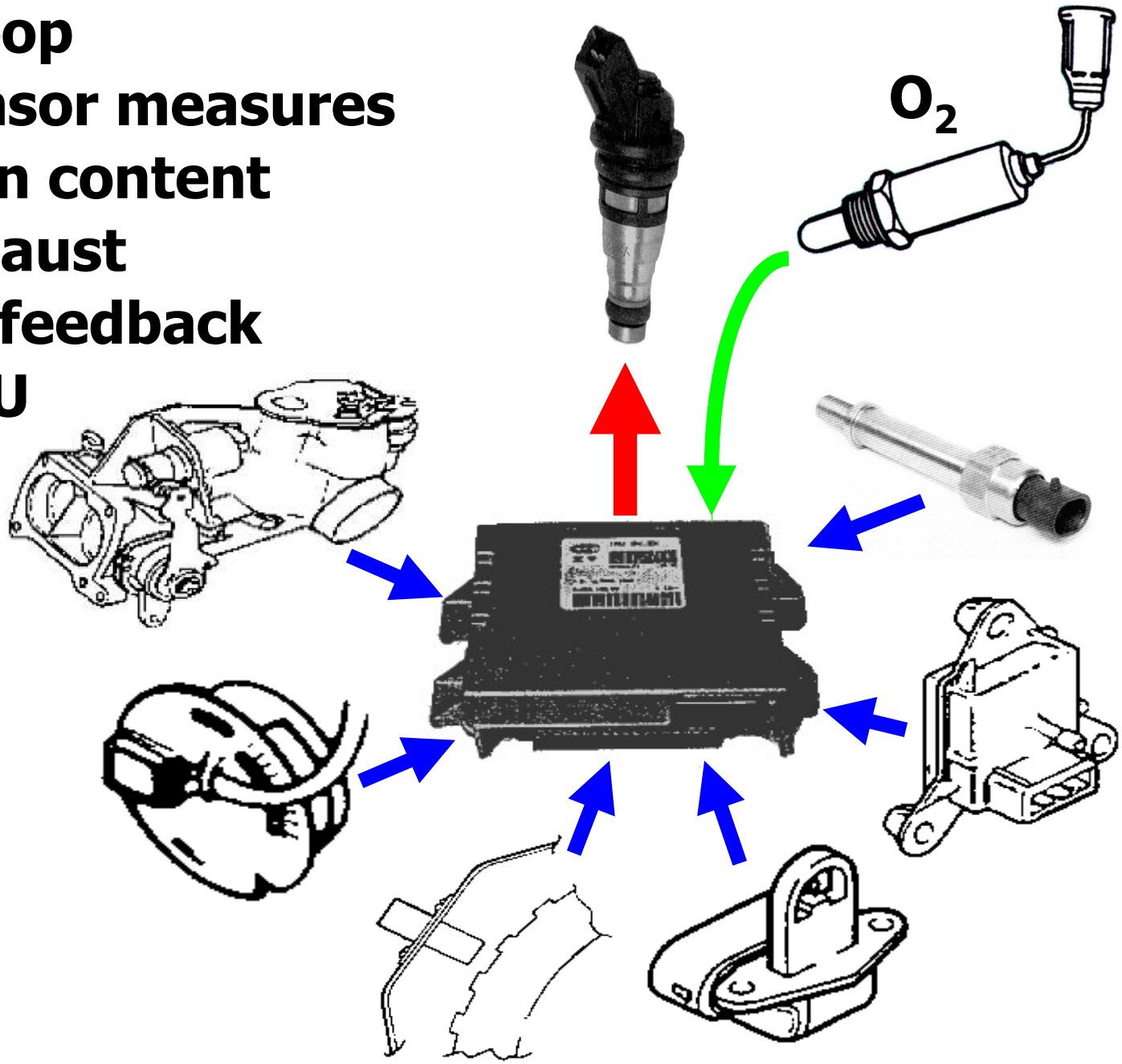
c. Most four-strokes

d. All two-strokes



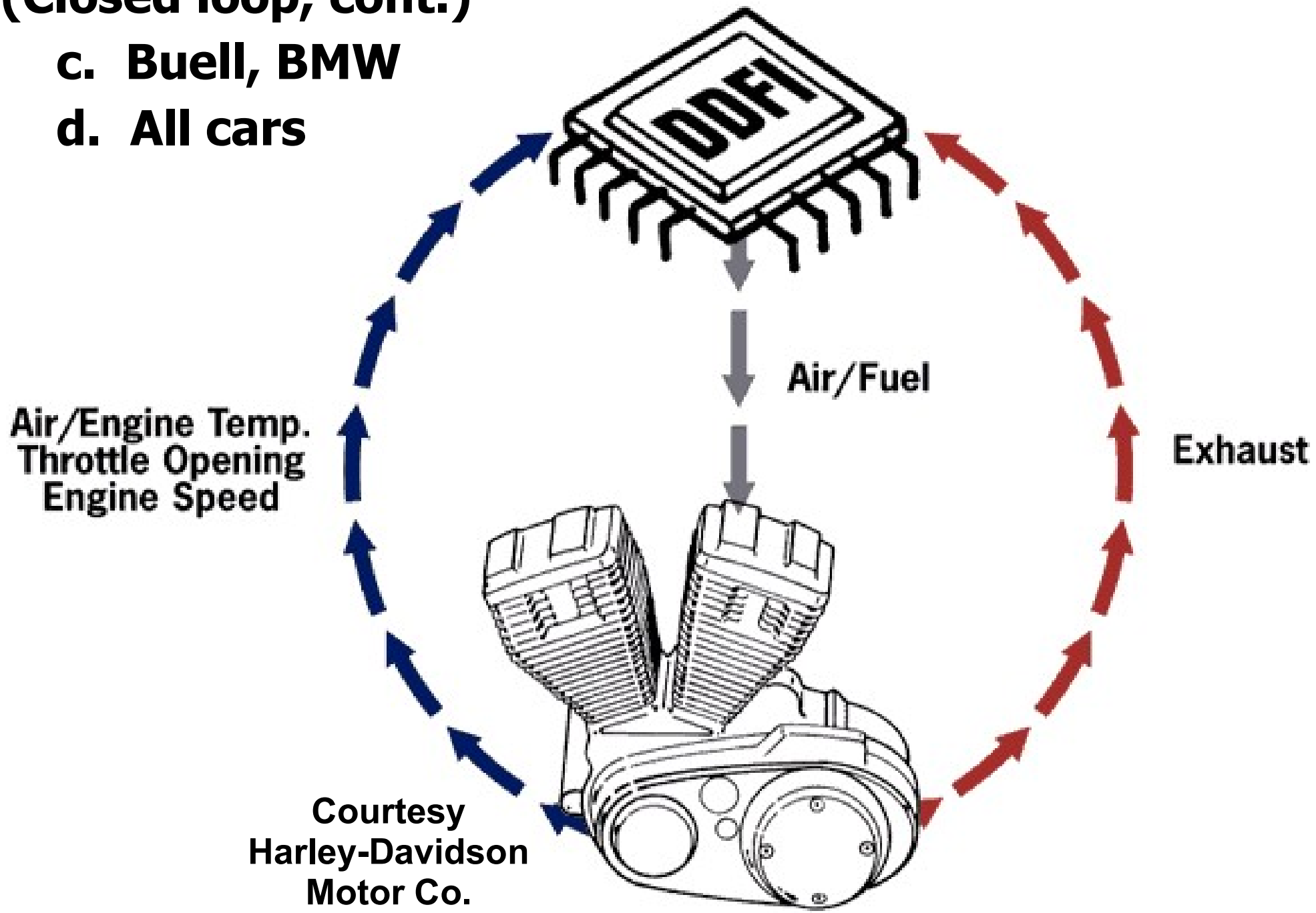
(Open vs. closed loop, cont.)

2. Closed loop
   a. O_2 sensor measures oxygen content of exhaust
   b. Gives feedback to ECU



(Closed loop, cont.)

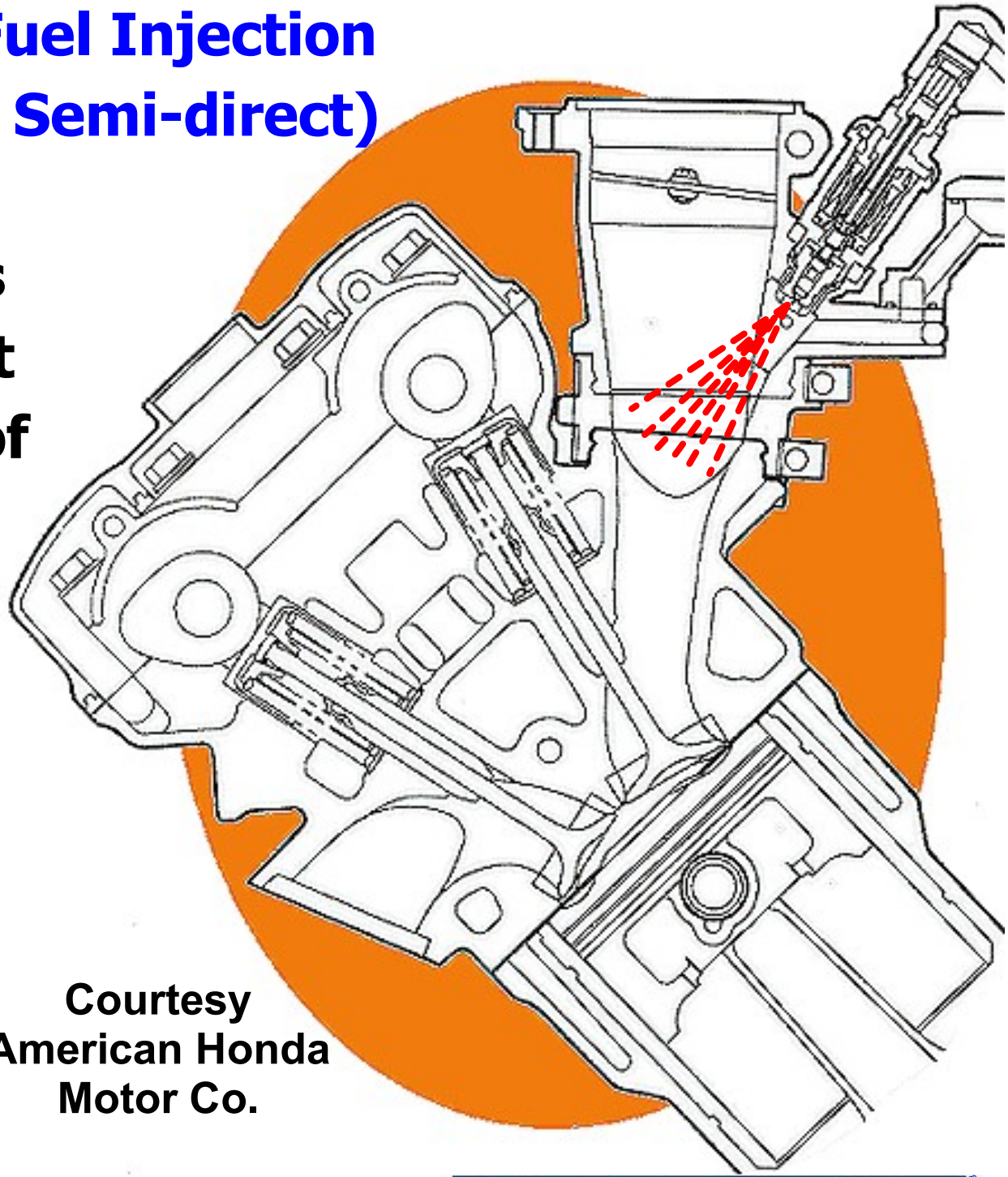
- c. Buell, BMW
- d. All cars



Courtesy
Harley-Davidson
Motor Co.

III. Three Types of Fuel Injection (Indirect, Direct, Semi-direct)

A. Indirect
   1. Fuel enters intake tract upstream of the valve
   2. Most common

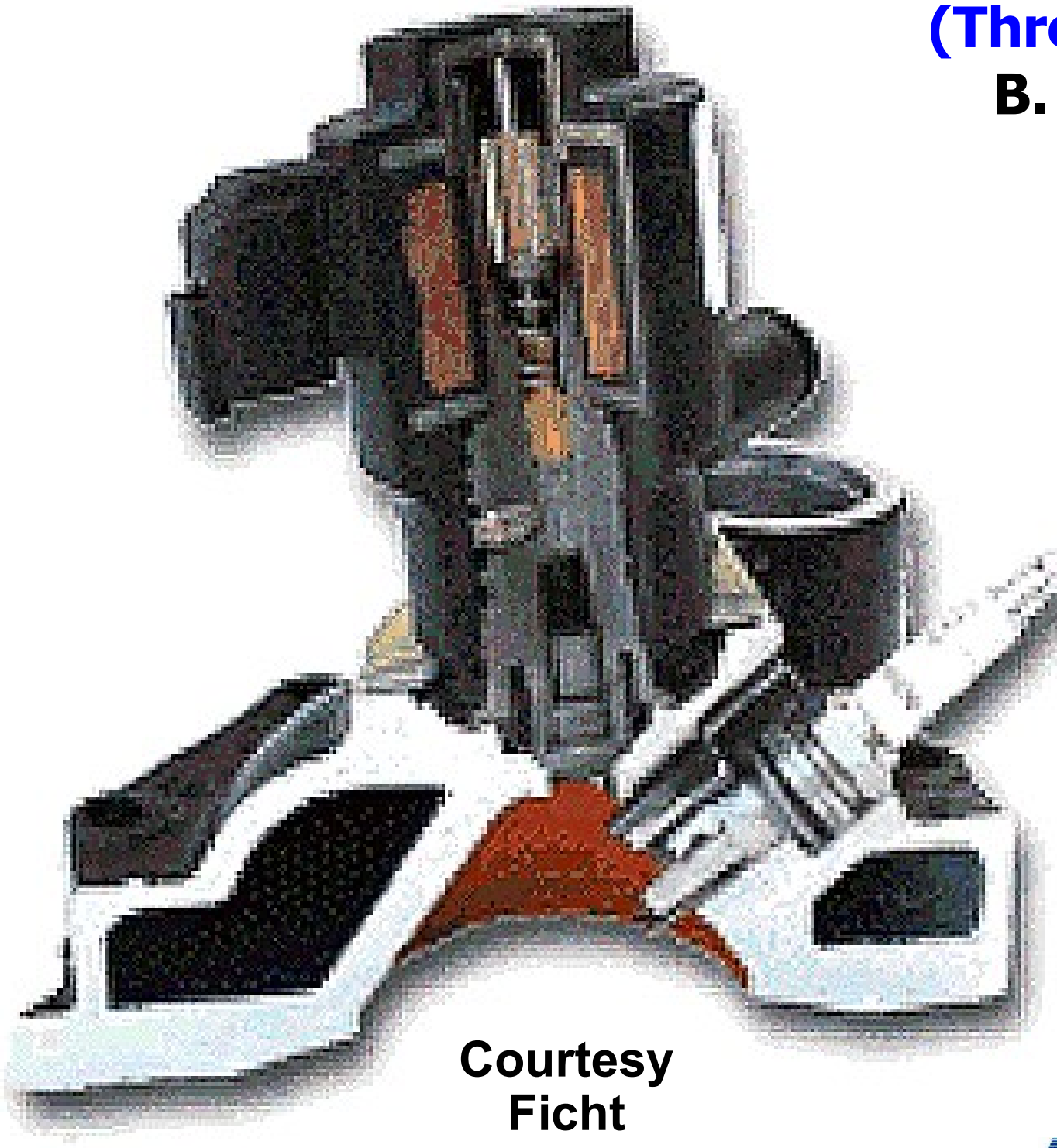


Courtesy
American Honda
Motor Co.

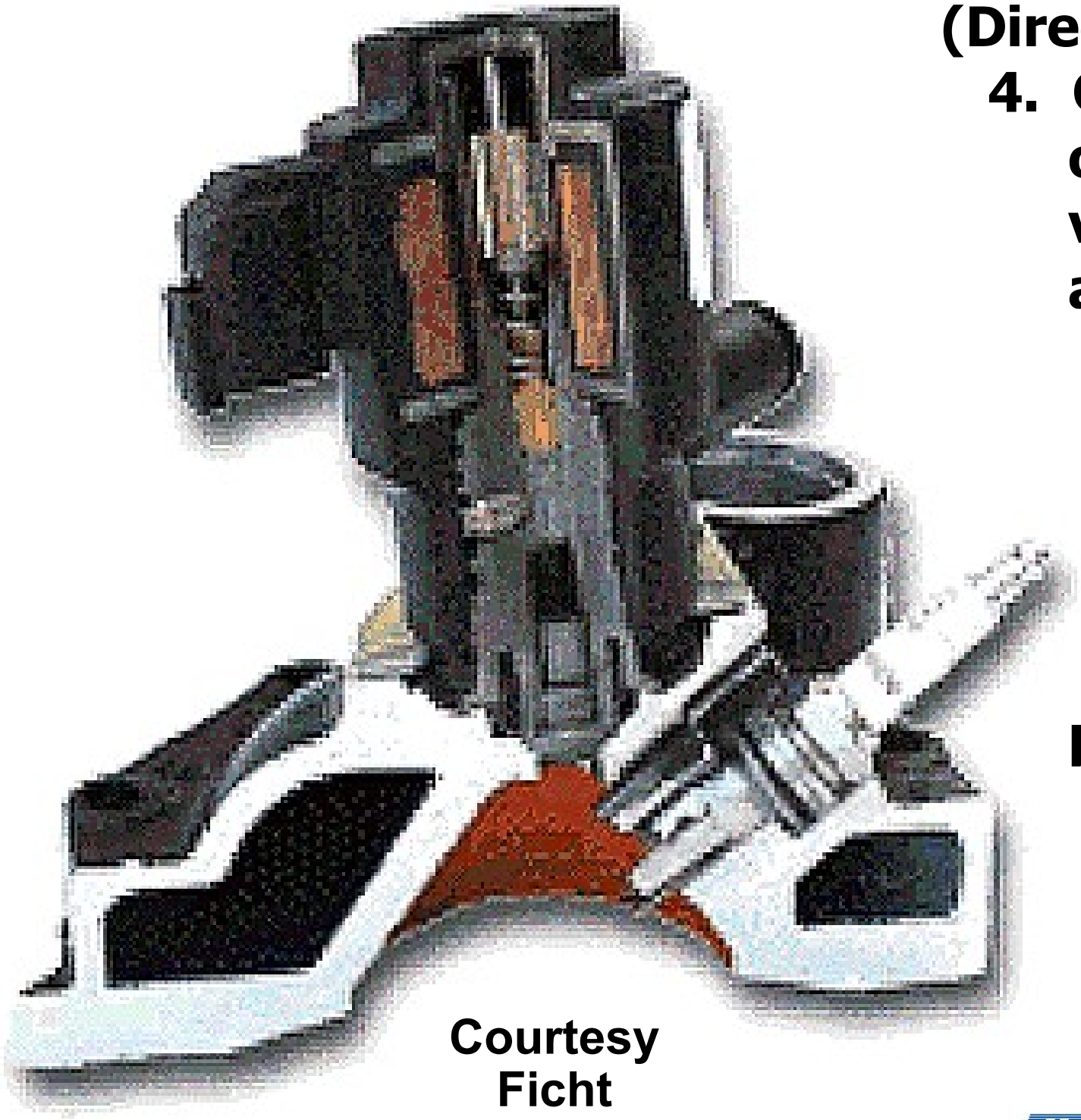
(Three Types, cont.)

B. Direct

1. Fuel injected directly into combustion chamber
2. Traditional low-pressure type used in diesel engines
3. Updated high-pressure version used in marine engines and personal water-craft



Courtesy
Ficht



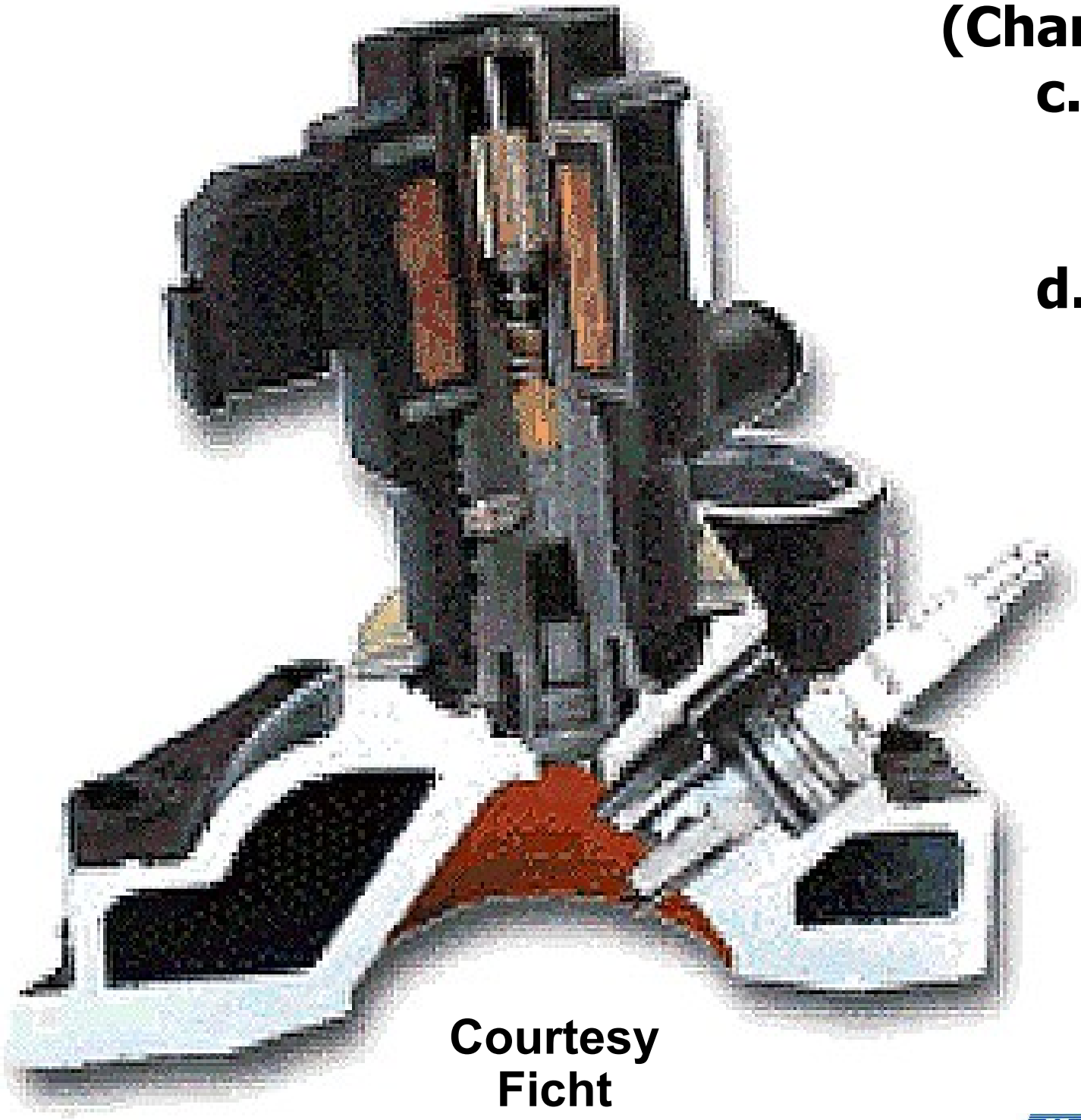
Courtesy
Ficht

(Direct, cont.)

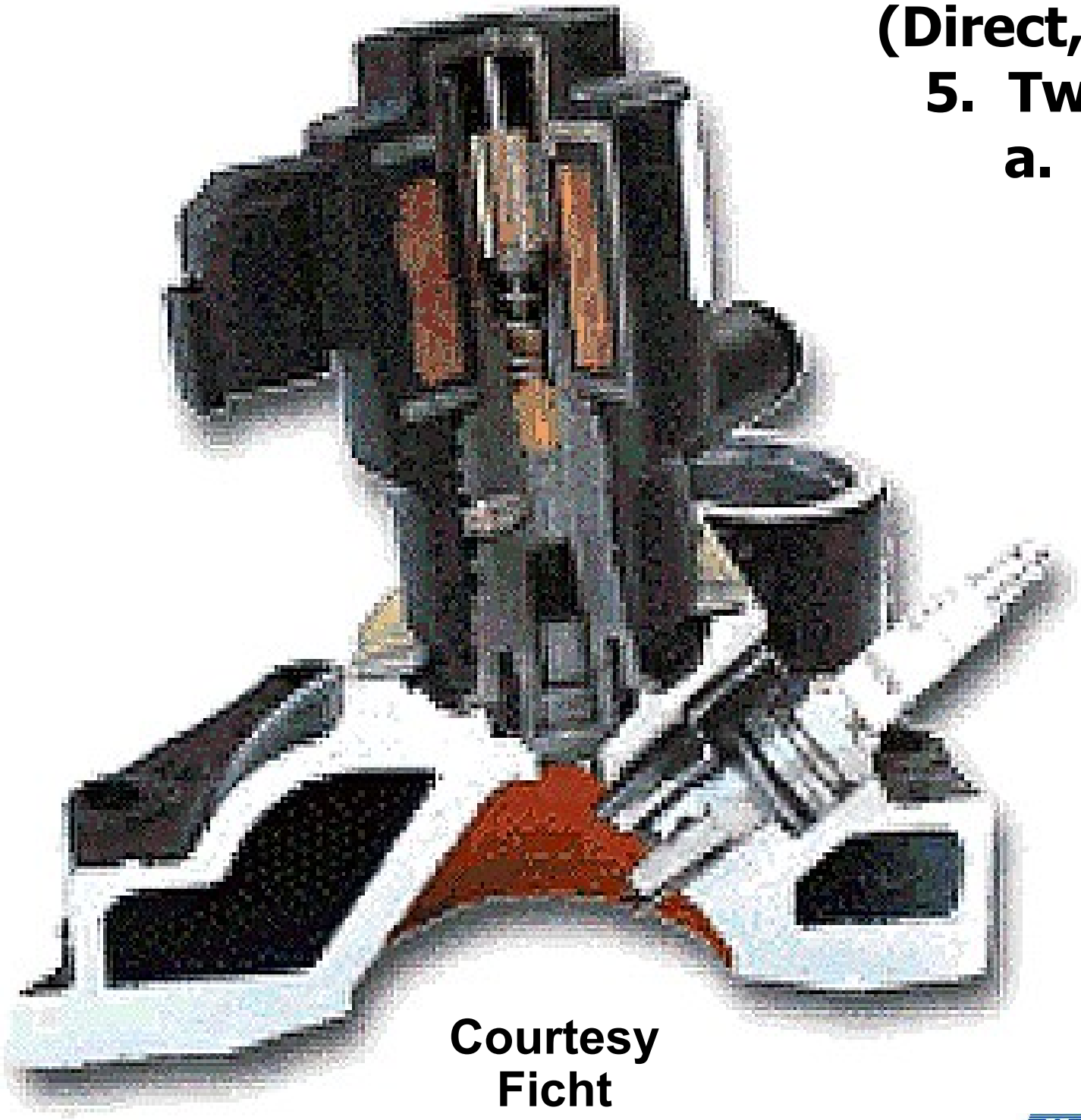
4. Characteristics of high-pressure version
   a. Injection is delayed until after the exh. port closes to minimize typical two-stroke charge loss
   b. To permit this delay, the injection must be faster

(Characteristics, cont.)

c. To be faster, it must be more forceful
d. The additional force is applied after the fuel pump, at the injector itself



Courtesy
Ficht



Courtesy
Ficht

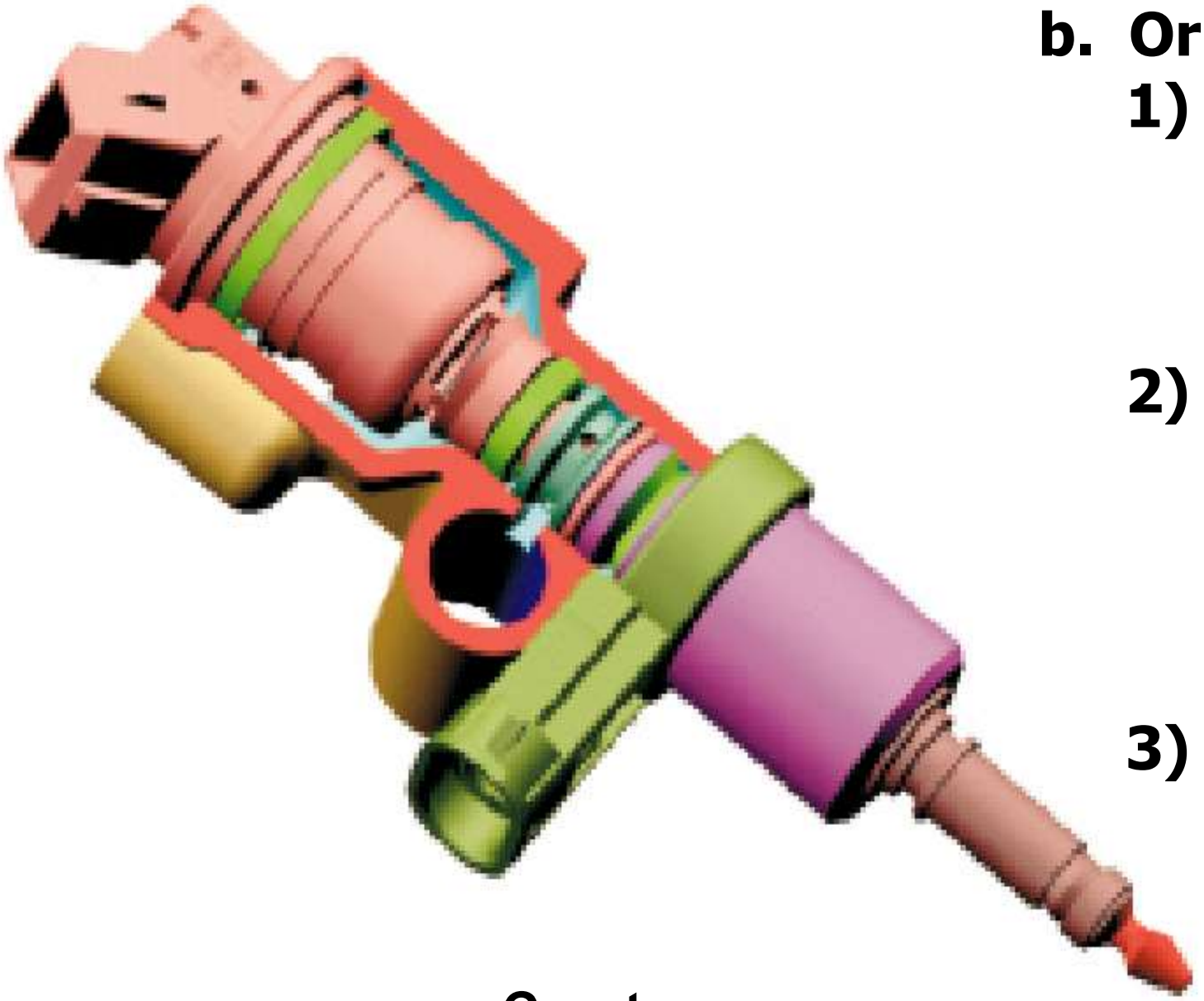
(Direct, cont.)

5. Two approaches
   a. Ficht system
      1) A plunger is built-into the injector
      2) The fuel's pressure is stepped up
      3) Used on Kawasaki, Polaris, Arctic Cat personal watercraft, OMC products

(Two approaches, cont.)

b. Orbital system

1) The pressure is added from outside the injector
2) This high-pressure air is pre-mixed with the fuel in the injector
3) Sea-Doo PWC, Honda motor-cycles, some cars



Courtesy
Orbital

(Direct, cont.)

6. Advantages of high-pressure direct injection
   a. Fuel/air plume is so highly atomized it is almost vapor-ized
   b. Less fuel waste
   c. Much lower exhaust emissions

(Three Types, cont.)

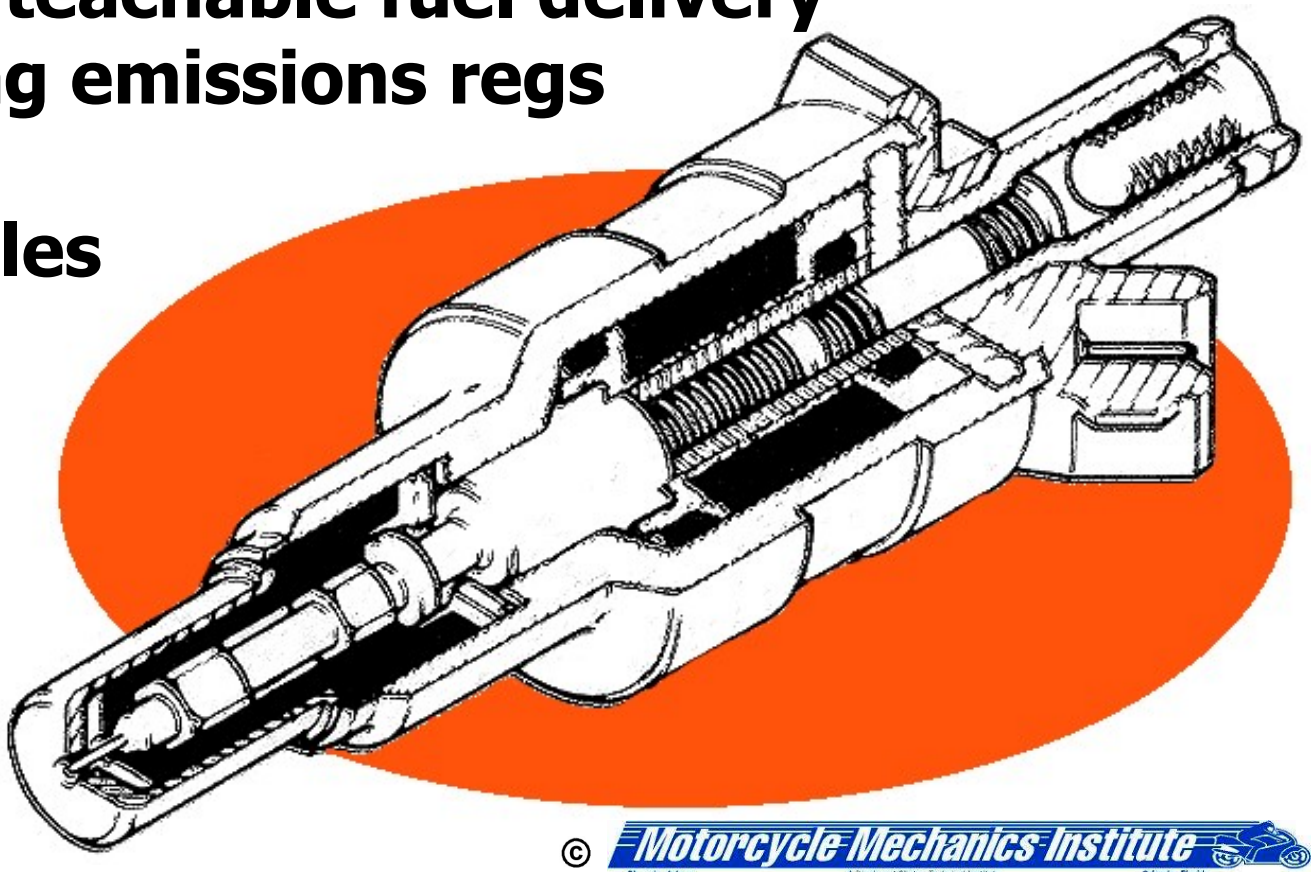
C. Semi-direct

a. Injectors in transfer ports

b. Includes separate cooling system for crankcase to compensate for reduced fuel in crankshaft area

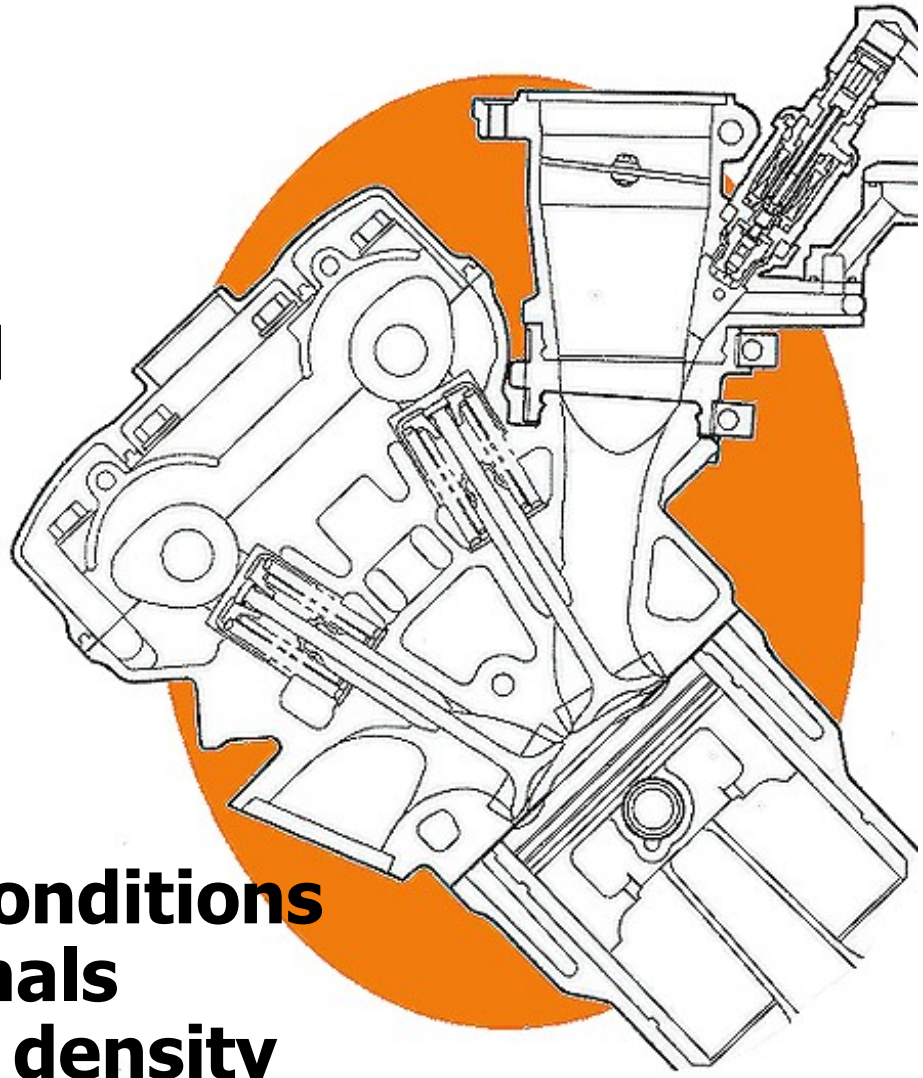
Review

- A. Introduction
  - 1. What
    - a. Electronically metered, timed, delivered
    - b. Replaces carburetor
  - 2. Why
    - a. Eliminate dependence on press. differences
    - b. "Smart," teachable fuel delivery
    - c. Increasing emissions regs
  - 3. Where
    - a. Motorcycles
    - b. PWC
    - c. Marine engines



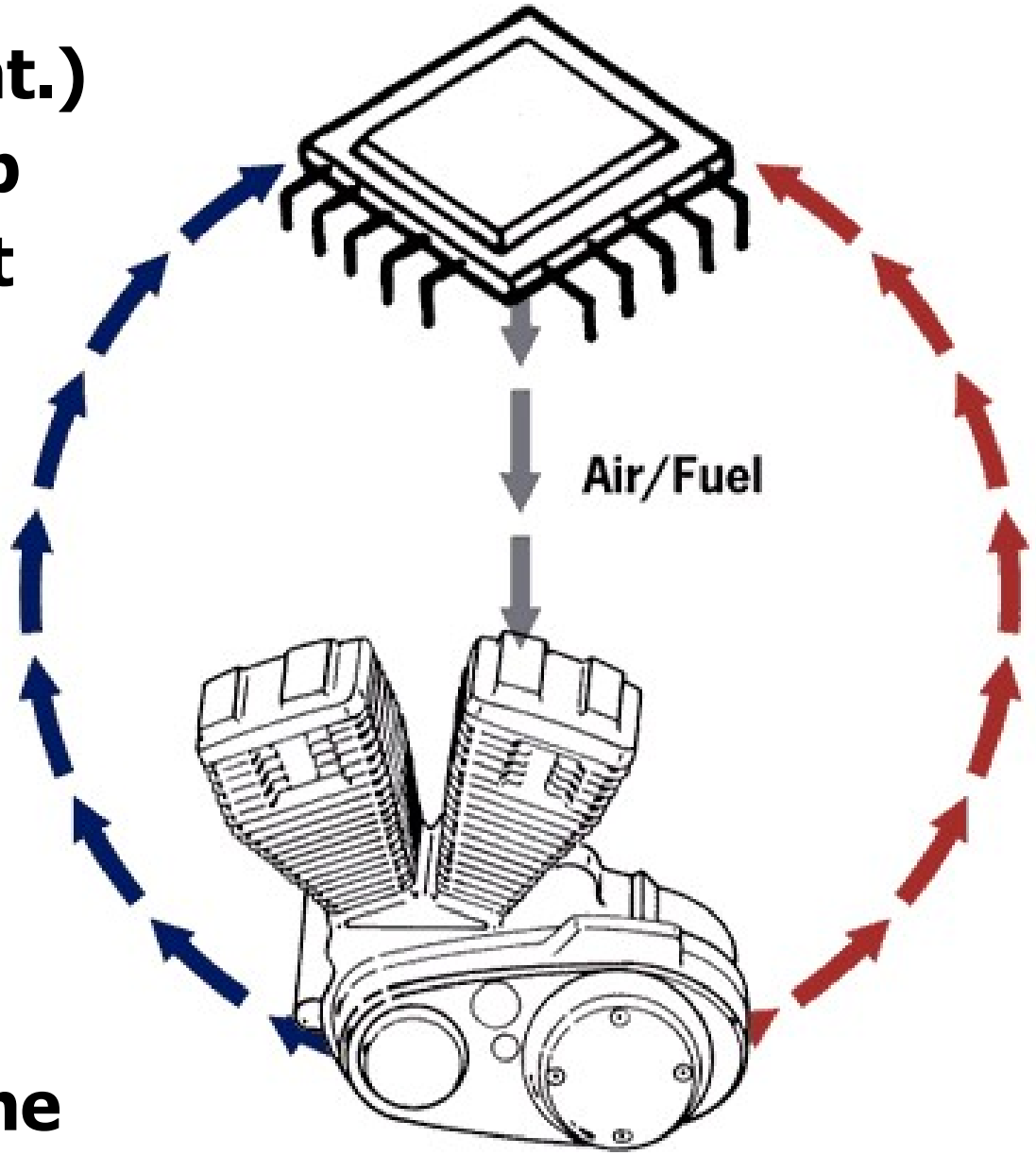
(Review, continued)

B. Basic Fuel Injection
   1. Injectors
      a. Solenoids
      b. Tiny hole(s) in end
      c. "Business" end
   2. ECU
      a. Computer
      b. Maps
      c. "Brains"
   3. Sensors
      a. Convert physical conditions into electronic signals
      b. Air volume and air density
      c. "Eyes and ears"
   4. Throttle body
      a. Physical replacement for carb
      b. Contains throttle butterflies
      c. The "breather"



(Basic Fuel Injection, cont.)

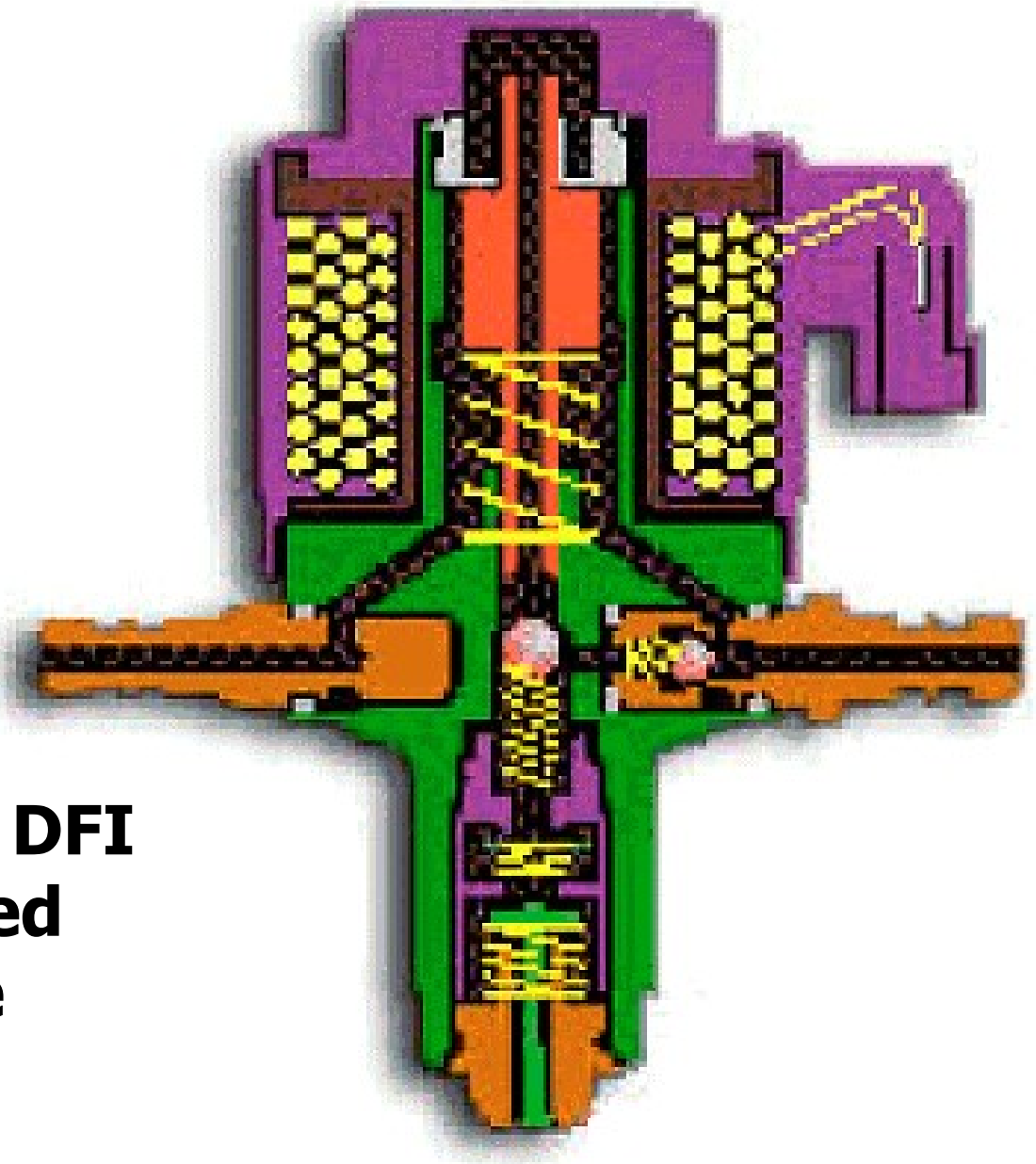
5. Closed vs. open loop
   a. Closed = exhaust feedback to ECU
   b. Open = no exhaust feedback
6. Advantages of fuel injection
   a. Superior atomization
   b. Centralized engine management



Courtesy
Harley-Davidson
Motor Co.

(Review, continued)

C. Three Types of Fuel Injection
   1. Indirect
      a. Upstream of intake valve
      b. Port injection
   2. Direct
      a. Into combust. chamber
      b. High pressure DFI
      c. Highly atomized fuel/air plume
      d. Ficht, Orbital
   3. Semi-direct
      a. Transfer ports
      b. Rotax RFI



(Review, continued)

D. Advantages of Fuel Injection

1. Consistent fuel delivery
2. Superior atomization
3. Increased fuel efficiency
4. More centralized engine management
5. More power with fewer emissions