

Avoiding Fuel Starvation in the BMW E36 M3 via the Installation of Twin Fuel Pumps

Introduction

Under racing conditions, the engine in the BMW E36 M3 may "starve" for fuel when the amount of gasoline in its tanks falls below a certain level. This Application Guide details the installation of twin fuel pumps on a 1995 M3 Lightweight to alleviate this problem.



Figure 1: 1995 BMW E36 M3 Lightweight

Normal Operation

The E36 3 series¹ uses a molded one-piece plastic fuel tank under the rear passenger seats. A small passage over the driveshaft connects the two tank halves. Fuel is added through the filler pipe. Fuel is extracted from the right-hand-side² (*rhs*) of the fuel tank via an in-tank fuel pump. The fuel passes through a filter and pressurizes the fuel rail, to which the injectors are attached. At the

end of the fuel rail is the fuel pressure regulator (*FPR*). It maintains a constant fuel pressure relative to atmospheric pressure and returns excess fuel to the left-hand-side (*lhs*) of the fuel tank.

Since the crossover tube is located at the *top* of the fuel tank, the fuel levels in the left and right side of the tank cannot be equalized without some type of *siphoning* arrangement. The siphon works to equalize the level of the two tanks. Fuel is returned (under pressure) to the lhs tank, and over time the siphon equalizes the levels in the two tanks.

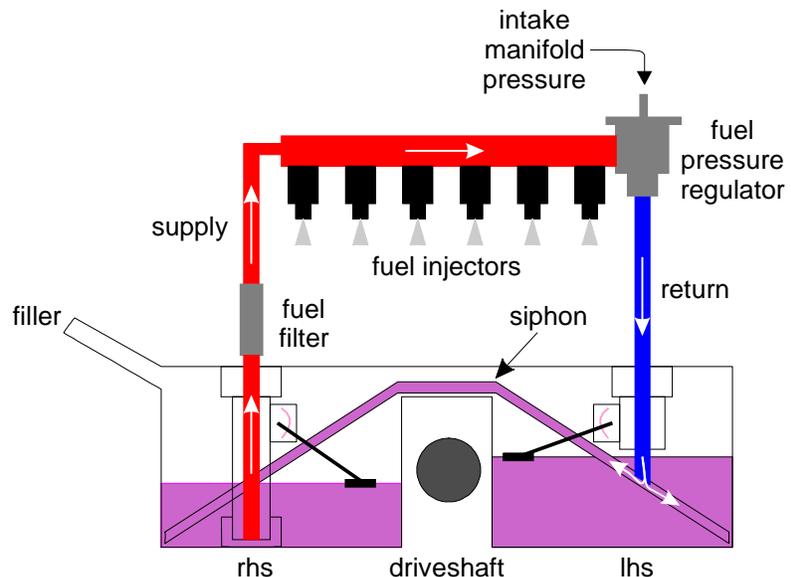


Figure 2: E36 M3 Fuel Delivery and Return System

As shown in Figure 2, the siphon is combined with the return line to facilitate active transfer of fuel from the lhs of the tank to the rhs, where the pump and reserve sump are located.

Over the course of E36 3-series production of USA models, BMW changed the fuel and delivery return systems at the fuel tank. Prior to models built in January of 1995, fuel was returned to the lhs, and excess fuel was then routed from the lhs to the rhs tank *externally*. Starting in January of 1995, the siphon was made *internal*. Consequently, the fuel pump, fuel level senders and fuel line arrangements differ between the early and later cars, and between OBDI and OBDII cars. European models may have had a different build history.³

Reserve Tank

The reserve tank is implemented as a miniature sump inside the rhs tank, directly below the fuel pump.

Fuel Level Senders

There are two fuel level senders – one in each side of the tank. Each uses a float arm with a wiper that travels over a thick-film resistor. The senders are connected in series to indicate the overall fuel level.

Racing Conditions Reveal a Design Weakness

Under racing conditions, the fuel in the fuel tank is subjected to substantial lateral g-forces. Many (but curiously not all) racing M3s experience fuel starvation in high-speed right-hand turns lasting more than a few seconds when the overall fuel level drops below ½-tank. The result is an instantaneous shutoff or near-shutoff of the motor – a highly undesirable racing occurrence. The driver usually regains his or her composure after the turn's exit.

A plausible explanation for this behavior is that the lateral forces are causing the fuel in the rhs tank (where the fuel pump is located) to move away from the fuel pick-up area, and *the fuel is being returned to the lhs tank faster than the siphon can equalize the lhs and rhs fuel levels*. These leads to an inadequate fuel level in the vicinity of the pump's pickup, and to fuel starvation.

Possible Solutions

Fuel Cells

For sanctioning bodies that require it, a competition fuel cell⁴ will solve fuel delivery problems. However, there is currently no fuel cell available to fit the E36 M3 in its stock location. Most E36 M3 fuel cells are installed in the spare tire well out of necessity, to the detriment of the E36 M3's near-perfect weight distribution.

Fuel Cell Foam

An alternative is to fill the stock fuel tank with an open-cell foam that is specifically designed for use in fuel cells. This helps prevent fuel "slosh", but won't solve the siphon problem. The foam should be replaced every three to five years.

Twin Pumps

By adding a second fuel pump to the fuel tank, we can ensure that at least one pump will not run dry during hard cornering. We'll now detail the installation of the second pump into an E36 M3 Lightweight, built in September of 1995.

Warning

WARNING Gasoline and racing fuels are highly flammable. You should not undertake this modification unless you are absolutely sure you have eliminated any and all sources of ignition from your workspace, including but not limited to cigarettes, open flames, electrical sparks, etc.

Perform this modification only if you are a competent mechanic and you can guarantee your safety and the safety of any and all persons who will drive, ride in and/or come in contact with an M3 so modified.

The author and Pumpkin, Inc. assume no liability whatsoever for the information contained herein. Use at your own risk.

Complete Kits

Some vendors offer model- and year-specific complete kits for sale. See *Sources*, below, for more information.

Parts Required

If you want to do this job yourself, the following parts are required. The BMW-specific parts can be obtained from BMW dealers or through OEM channels. Sources for parts without BMW part numbers are listed below:

Qty	Description	Part Number	Source
2*	fuel pump assembly	16 14 1 182 842	BMW / OEM
2 (optional)	lock	16 11 1 181 142	BMW / OEM
2 (optional)	rubber ring	16 11 1 179 637	BMW / OEM
3 meters†	8x13mm fuel hose	RHO-032A	Global Metrics
1 meter†	12x18mm fuel hose	RHO-024A	Global Metrics
2	8mm fuel hose "T"	828-60606	Global Metrics
8†	8-14mm hose clamps	ADZ-N04	Global Metrics
4†	12-20mm hose clamps	ADZ-N08	Global Metrics
1	fuel pump wiring harness		Parts Recycler
1	fuel filter	model-specific	BMW
2	8mm-to-12mm fuel hose adapter		Fabricated (see drawing at end of document)

Table 1: Parts Required for Dual-Pump Conversion

*: Pre-1/95 cars can re-use their existing rhs fuel pump (assuming the return bib is designed for 12mm fuel hose). Cars built 1/95 and later must use two new pumps.

†: These quantities are for the particular hose layout illustrated below (Figure 14). Other layouts may require different amounts of fuel hose and numbers of hose clamps.

Fuel Pump Assemblies



**Figure 3: Fuel Pump Assembly: BMW P/N
16 14 1 182 842**

Figure 3 shows right-side (left) and front views (right) of the fuel pump assemblies we'll be installing. On the pump at left, the fuel level sender is at the lowest position. On the pump at right, it's in roughly its mid-range position. The clear flexible lines from the fuel pumps (the silver cylinders is mounted to the plastic body via a rubber suspension) exit through the top of the plastic housings via an 8mm bib, and are capped off with black plastic plugs when new. Not visible are the 12mm bosses for the return lines, which simply dump fuel down the back of the plastic housings.

The fuel pump assemblies do not employ a keying scheme to limit installation to a particular orientation. However, the dimensions of the fuel tank and the geometry of the fuel pump assembly force the fuel pump assembly to be installed in only one orientation – with the fuel pump pickup pointing down and towards the rear of the car.

Fuel Hoses and Adapters



Figure 4: 8mm Fuel Hose, Adapters and Ts

Figure 4 shows two meters of 8mm fuel hose (marked BMW 8x13), two 8-to-12mm hose adapters and two 8mm Ts. While the Ts are readily available, the 8mm-to-12mm adapters are not. I made mine from AMPCO-45 cylindrical bar stock on a lathe – a fabrication drawing for use with hose clamps of 3/8" width⁵ or less is provided at the end of this document. The 12mm hose is marked BMW 12x18. Good fuel hose is expensive – don't skimp on safety by purchasing something of lesser quality.

Wiring Harness



Figure 5: Fuel Pump Harness

Later cars will need additional wiring to energize the second fuel pump. It is rumored that earlier cars have the requisite connector already installed. The black connector in Figure 5 is for the fuel pump. The white connectors are for the fuel level senders. If your car does not have a lhs fuel pump connector, you'll need the black connector and its wires.

Tools Required

In addition to the usual tools required when working on BMWs, you should also have a very large standard screwdriver, a dead-blow hammer, a sharp knife or hose cutter, and parts to splice into an electrical harness. A Dremel tool capable of grinding plastic is also required.

You should also obtain a service manual for your car. The Bentley manual has a good set of diagrams and pictures in its *Fuel Tank and Fuel Pump* chapter.

Before You Begin

It's advisable to do this modification when the fuel tank is nearly empty. Therefore you should drive the car until the empty light comes on.

Note The procedure outlined below is for cars built on or after 1/95. If your car was built before 1/95, your existing fuel pump can be reused, and need not be removed. You will still have to re-route some the fuel lines, however.

WARNING Disconnect the battery before working on or around the fuel tank.

Installing Twin Fuel Pumps

Gaining Access to the Fuel Tanks

1. Remove the rear set bottom by pulling it up and out.
2. Remove the dinner-plate-sized ribbed sheet metal covers above the lhs and rhs fuel tank access ports. Each is secured with four sheet metal screws.
3. Disconnect the fuel pump connector (rhs) and fuel level sender (lhs and rhs) connectors. They are keyed, so you needn't worry about which goes where.
4. At this point you may want to clean any dust or debris that may have collected on top of the pump (rhs) and level sender (lhs). Compressed air is just the ticket here. Once you remove the pump and sensor, the tank will be open, and you won't want any junk or other items falling inside.

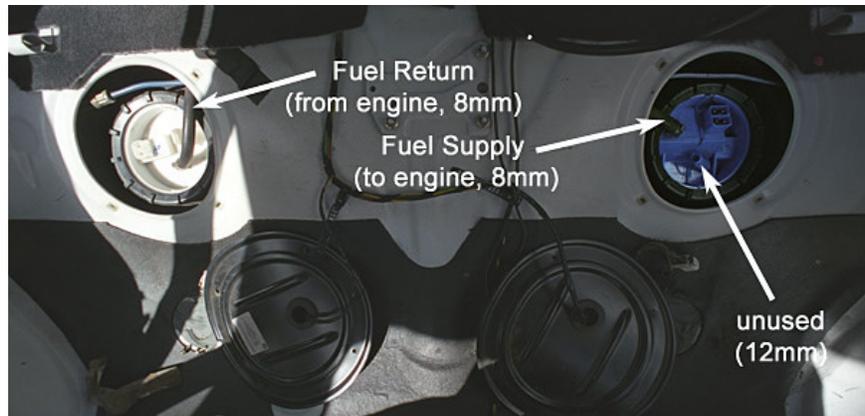


Figure 6: Stock Fuel Supply and Return Layout (1/95 and later)

In Figure 6 you can see the pump+sender (rhs, blue) and sender only (lhs, white) of the later cars with their internal cross-tank siphon. Note the unused 12mm bib on the pump (it goes nowhere). Note also that there are two 2-pole electrical connectors on the rhs (one for the sender, and one for the pump) whereas the lhs has only one. The blue plastic tubing across the top of the openings is a vapor return line.

5. Label and disconnect the fuel lines. You'll want to plug any lines that drain back to the tank to avoid spilling gasoline all over the place.

Removing the Pump and Sender Units

1. The pump+sender (rhs) and sender-only (lhs) units are captured in place via a large plastic locking ring (see Figure 7). A rubber seal is used to seal each one into the tank. BMW specifies a special tool for removing the sealing rings (they unscrew counterclockwise), but a large standard screwdriver will also work. Just place the tip against one of the ring's ribs and hammer away, hard enough to move the ring but not too hard – you don't want to break it. At first, the ring will move very slowly, but after approximately a ¼-turn it will require less force. Unscrew each ring completely.



Figure 7: Sealing Ring

2. With the rings removed, you can lift out the rhs pump+sender unit.



Figure 8: Stock Fuel Pump with Sender, Side View

Figure 8 is a close-up of the stock pump that was removed from a 9/95 build date M3. This pump is identical to the earlier pumps, except for the blue plastic body and the fact that a working 12mm return hose bib is not present.

Have a rag or container handy to place the pump in so as to avoid spilling gasoline over the car's interior. The sealing ring (see Figure 9) may come out with the pump+sender unit – clean it and place it aside for later reuse.



Figure 9: Fuel Pump Seal (Top View)

On the later cars, the lhs sender unit has the siphon attached to it. You'll need to extract both the sender unit and the siphon – don't leave the siphon in the tank. The siphon assembly is affixed to the lhs sender unit. Some force may be required to separate the two. Again, recover, clean and set aside the seal.



Figure 10: View Inside rhs Tank -- Reserve Sump

In Figure 10⁶ you can make out the reserve sump – a white plastic labyrinth sump at the bottom of the rhs tank. The fuel pump's pick-up screen lies within the walls of this sump.

Modifying the LHS Pump

The rhs of the fuel tank will readily accommodate any E36 fuel pump assembly. The lhs, however, is not as deep, and was not designed to accommodate a fuel pump assembly. In order to fit the pump into the lhs tank, you will need to reorient the fuel level sender by 90 degrees clockwise (when viewed from the top):

1. Remove a small amount of material from the pump body (shown in Figure 11) for clearance using a Dremel or similar tool.
2. The level sender is held in place via a spring and a +-shaped cutout in the pump body. You'll need to reorient it by pulling up on the pump body flange enough to rotate the sender by 90 degrees, and then release the flange so that it traps the +-shaped top of the sender in the new orientation.
3. You may also have to bend the "arm" of the level sender slightly to ensure that it does not bind in its new orientation. Check to see

that the sender is fully seated in the lower flange of the pump body – if not, push the sender unit up and out of the way, and repeat step 1 above.

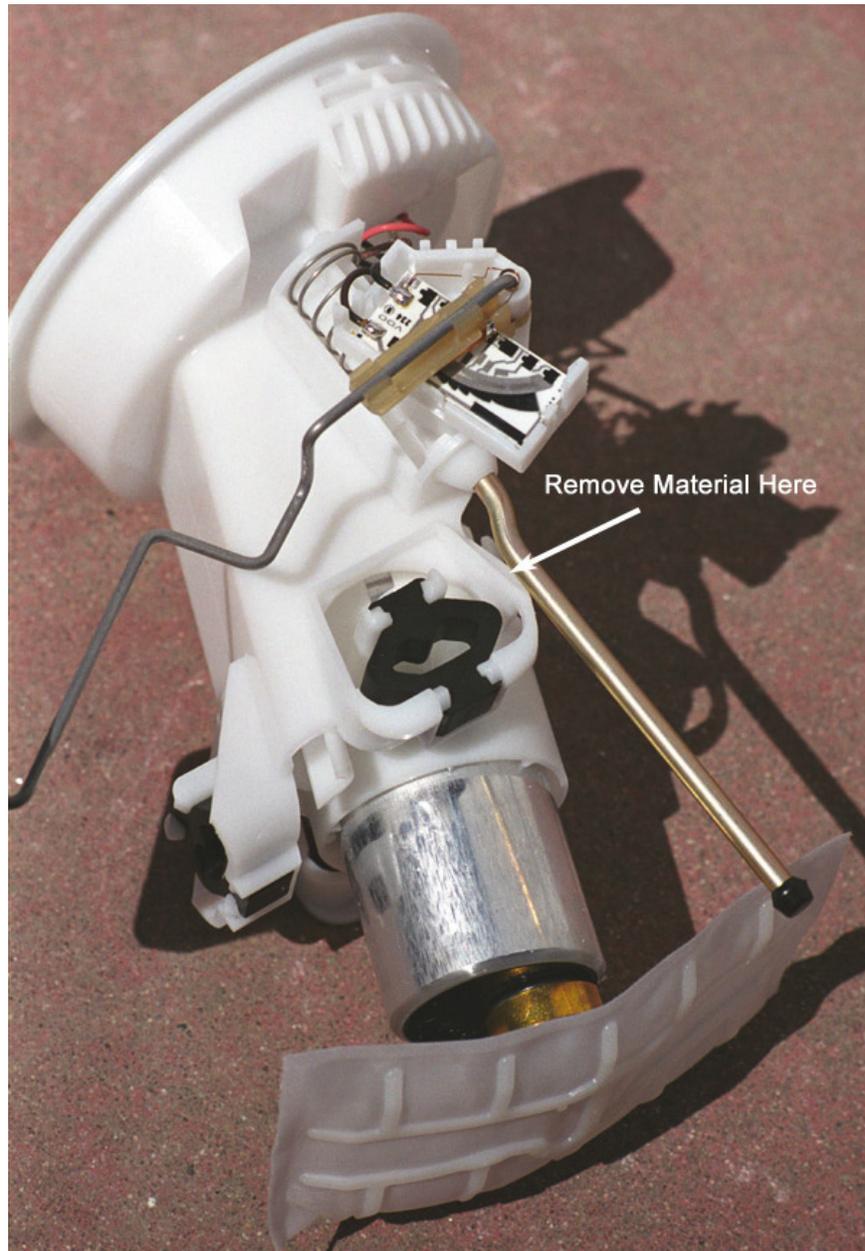


Figure 11: Pump Body Interferes with Reoriented Sender Unit

Figure 12 shows a stock pump (left), suitable for the rhs tank, and a modified stock pump (right), suitable for the lhs tank. The re-orientation of the fuel level sender is necessary for the sender to be able to move freely over its full range of travel.



Figure 12: Comparison of Stock and Modified Pump Assemblies

Routing the Fuel Lines

Once the two pumps are in place and the sealing rings have been tightened, you can connect all of the fuel hoses. The basic idea is that each pump feeds into a T, whose single outlet goes to the FPR. Similarly, the return line from the FPR goes to another T, whose twin outlets go to the return pipes on the pumps. All of the fuel hoses are 8mm i.d. except for the two return pipes on the pumps, which are 12mm i.d. Therefore 8-to-12mm i.d. adapters are required between the outlets of the return T and the return bibs on the fuel pumps.

The actual locations of the various Ts and adapters are not too critical. It's more important that your layout ensure that the sharp edges of the hose clamps do not rub against any other hoses, and that there are no sharp kinks in any of the hoses. I ended up using the car's original feed hose but replaced the original return hose.

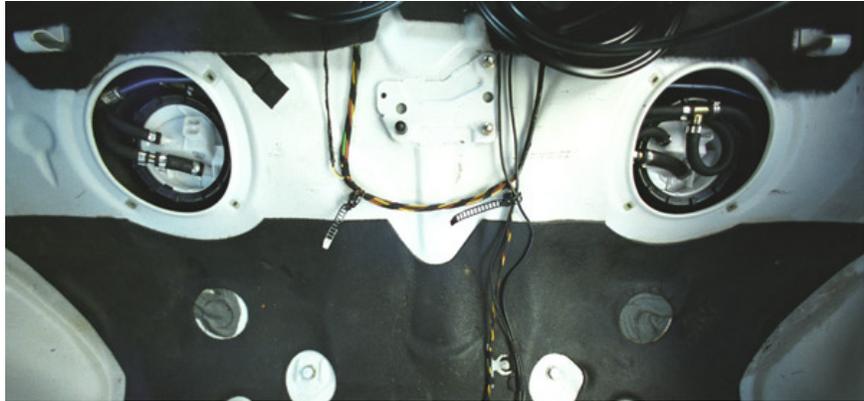


Figure 13: All Done Routing the Fuel Lines

Figure 14 illustrates the fuel routing for twin pumps. The T for the supply lines is located above the rhs pump and can be seen in Figure 13. The T for the return lines is located ahead of and slightly below the top of the lhs pump, and is barely visible in Figure 13. The 8-to-12mm i.d. adapters are located between the 8mm fuel return lines and very short runs of 12mm fuel hose that attach to the return bibs on the pumps.

I used Oetiker-type band clamps because of their smaller size and fewer sharp edges when compared to conventional clamps.

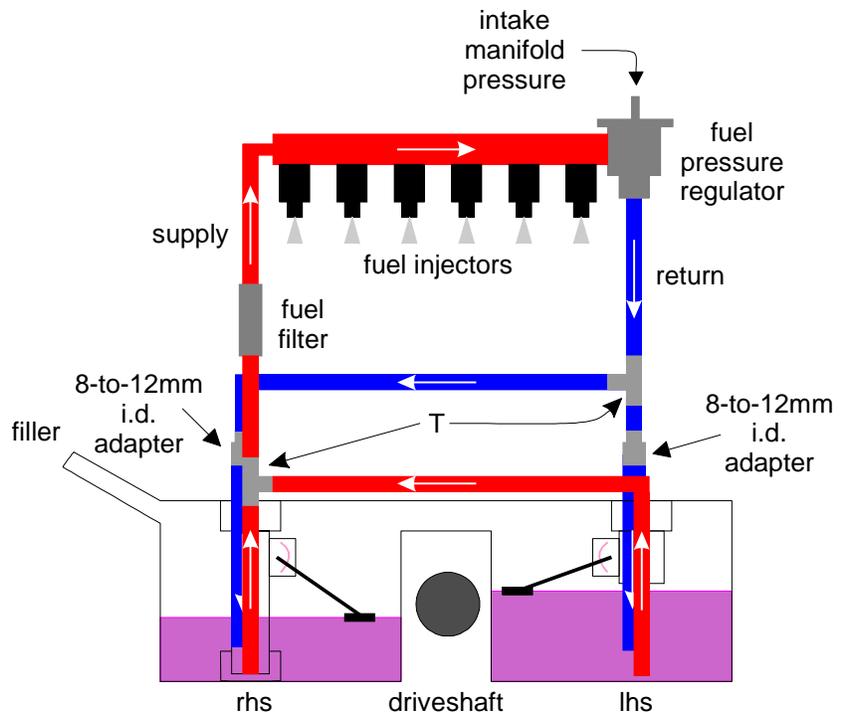


Figure 14: Fuel Routing Diagram for Twin Fuel Pumps

Wiring in the Second Pump

The fuel pumps each require a 15A fuse. Some people have spliced the extra connector for the second pump into the first's pump's harness and upped the fuse to 20A. Because of the high currents involved, I chose to wire the second pump via a relay connected directly to the battery, as illustrated in Figure 15.

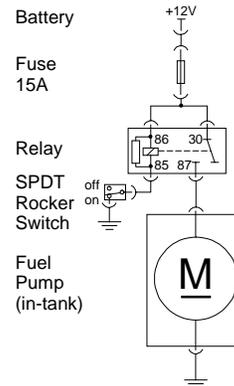


Figure 15: Wiring for Second Fuel Pump

I control the relay via a rocker switch in the center console next to the 12V accessory outlet. The switch grounds the relay coil to switch the fuel pump on.

An alternative wiring scheme would be to power the second pump's relay's coil from the +12V feed of the first (stock) pump. This would ensure that if the pump feed is cutoff (e.g. due to the E36's impact switch being tripped), both fuel pumps will turn off. Yet each pump still gets its own, separate high-current +12V feed. However, this scheme has the disadvantage that if the first fuel pump's fuse blows, both pumps will turn off.

Ideally, each pump's relay's coil should be connected to an impact-protected +12V line, and each pump should have its own, dedicated and fused +12V high-current feed through a relay.

Results

Without the twin fuel pumps, the author's car would starve for fuel in turn 4 at Laguna Seca and turns 5A and 15 at Thunderhill with 3/8 or less of fuel in the tank. With the twin pumps, the car can be driven without any signs of fuel starvation until the empty light illuminates. Fuel starvation usually occurs with about 1 gallon left in the tank.

Note Since the lhs tank does not have a reserve sump, the lhs pump will "go dry" before the rhs pump. Therefore when the empty light illuminates and the car is at a stop, the lhs pump will starve for fuel and make some pretty awful noises.

Observations

Whenever the fuel level is below ½ tank, I run the car with both pumps turned on. At idle and at rest, with the empty light on, it's often *necessary* to run the second (lhs) pump, otherwise the engine cuts out for lack of fuel.

Measurements

Figure 16 illustrates the effect of twin fuel pumps on the M3's fuel pressure.⁷ This seems to suggest that the FPR can handle the additional pump without incident, and that external check valves are not required.

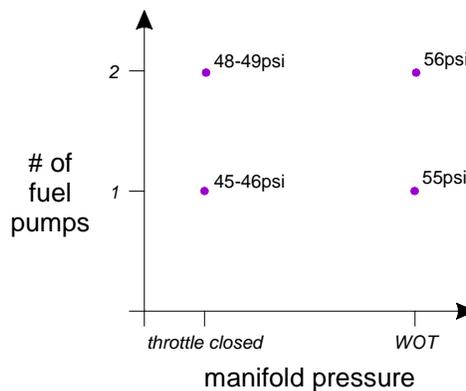


Figure 16: Effect of Twin Pumps on Fuel Pressure

Alternative Layouts

An alternative layout can be implemented using two different pumps (one with feed and return bibs, one with only a feed bib). The pump outputs meet in a T and feed the engine. But the return line from the engine goes only to the rhs pump. No siphon is employed between the two tank halves. This layout appears to work quite well, and suggests that there is a lot of passive transfer of fuel between the two tank halves under racing conditions.

With this layout there is some concern that the lhs pump will be running dry because of the lack of active return to the lhs tank.

Acknowledgements

The author wishes to acknowledge the help of BMW CCA Club racers Richard Biscevic, Scott Smith, John Fisher and Bob Butler in collecting material and information for this Application Guide. Also, Adam Reif created the fabrication drawing for the 8mm-to-12mm fuel line adapter.

M3-Specific Details

The E36 M3 Lightweight shown in Figure 1 belongs to the author. At the time the photo was taken in 2004, the M3 was factory-stock, save for the following modifications:

- Window net
- -3.3° front camber
- Electrical disconnect
- Fire suppression system
- SSR Integral 17x8 wheels
- Quick-release steering wheel
- Koni single-adjustable shocks
- 5-point quick-release safety belts
- Finned differential cover / cooler
- Racing brake pads (PF, Pagid, etc.)
- On-board data acquisition with GPS
- Rear seat cushions and backs deleted
- Stock front seats replaced with racing shells
- Weld-in 6-point 1.75" x 0.120" DOM steel safety cage, not tied to suspension pick-up points
- DOT R-compound tires in 235/40-17 (Yokohama A032R, Toyo RA-1) or 245/40-17 (Dunlop SP Super Sport Race) sizes
- All M3 Lightweight-specific off-road parts installed (front splitter, lower X-brace, upper strut bar, dual-pickup oil pan and rear wing)

This M3 Lightweight weighs approximately the same as when it was first delivered from the factory, at 2940 lbs. There are no engine or drivetrain modifications, no brake modifications, nor any suspension modifications beyond shocks and front camber.

Note The fuel starvation issues addressed in this guide occurred when the car was still 100% factory-stock, and continued until the twin fuel pumps were added.

Sources

Fuel Hoses, T's, Hose Clamps

Global Metrics, Inc.
519-J Marine View Avenue
Belmont, CA 94002
tel: (650) 592-2722, (800) 227-9981
fax: (650) 591-5396

Used BMW Wiring Harnesses

Double 02 Salvage
2034 American Avenue
Hayward, CA 94545
tel: (510) 782-2002
fax: (510) 782-2667

New BMW / OEM Parts

John Fisher
Fisher Motorsport
2232B Old MiddleField Way
Mountain View, CA 94043
tel: (650) 526-5580/5590
email: jfisher2@testeq.com

E36 Fuel Starvation Kits (Complete, model- and year-specific)

James Clay
Bimmerworld
1210 Grove Avenue
Radford, VA 24141
tel: (540) 639-9648
fax: (540) 633-1275
web: <http://www.bimmerworld.com/>
email: info@bimmerworld.com

Credits

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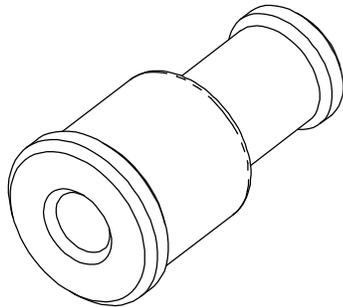
References

Robert Bentley, Inc., *BMW 3 Series Service Manual M3, 318i, 323i, 325i, 328i Sedan, Coupe and Convertible, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999*, Cambridge, Massachusetts, 1999.

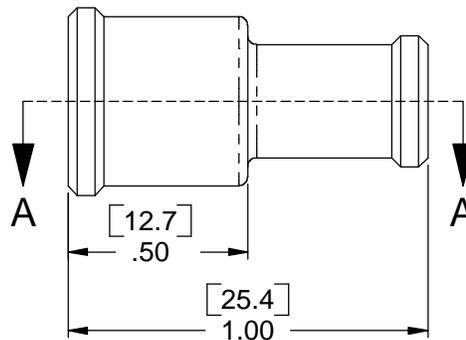
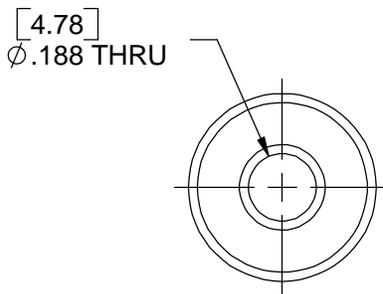
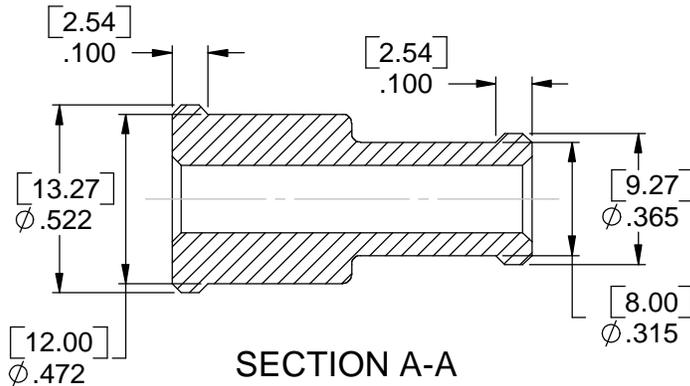
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- ¹ With the possible exception of the 318ti / Compact series.
 - ² Orientation is when sitting in the car facing forward. I.e. left-hand-side is driver side (US models), right-hand-side is passenger side.
 - ³ Scott Smith's '97 Gruppe N race M3 has the earlier style arrangement, with external siphon, etc.
 - ⁴ E.g. <http://www.fuelsafe.com/>.
 - ⁵ 0.400", actually.
 - ⁶ A AA-size battery is being used to plug the fuel supply hose. Now would be a good time to extinguish your smoking materials.
 - ⁷ Fuel pressure data courtesy Richard Biscevic, tested on another M3 Lightweight.

REVISION HISTORY

REV	DESCRIPTION	DATE	APPROVAL



DUAL DIMENSIONING:
[mm]
INCHES



NOTES:

- 1) THIS DRAWING IS PROVIDED FOR INFORMATIONAL PURPOSES ONLY. PUMPKIN INC. DOES NOT ASSUME ANY LIABILITY IF (FOR EXAMPLE) YOU BLOW UP YOUR CAR.
- 2) THIS ITEM IS NOT FOR SALE. IF YOU ARE ABLE, MAKE ONE FOR YOURSELF.
- 3) REGARDING CHOICE OF MATERIAL, USE OF ANY "NON-SPARKING" ALLOY IS RECOMMENDED, SUCH AS BRONZE, BRASS, AMPCO-45, OR SIMILAR.

MATERIAL: Bronze	FINISH: RMS-32	HEAT TREAT: NONE	WEIGHT: 0.5 ounce [15 grams]
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: FRACTIONS DECIMALS ANGLES .X = ± .010 .XX = ± .005 ± 0° 30" .XXX = ± .002			750 Naples - San Francisco, CA - 94112 (415) 584-6360 phone - (415) 585-7948 fax info@pumpkininc.com
	APPROVALS DRAWN: AWR CHECKED: AEK QUAL ENG:	DATE 04/16/2004 04/18/2004	8mm-to-12mm Fuel Line Adapter 703-00279
CAD GENERATED DRAWING, DO NOT MANUALLY UPDATE	DO NOT SCALE DRAWING	SCALE 2 : 1	SHEET 1 OF 1

8mm-to-12mm Fuel Line Adapter

SIZE **A** **703-00279** REV **A0**