

Thoughts About Engine Conversions or Re-Power Options for Buses

Lots of folks think (dream?) about having more power or getting better mileage or both with their bus. Almost any change in the engine compartment will cost at least \$10,000 and can run as much as \$40,000. Given the cost, why would anyone consider modifying their bus drive train?

JIM SHEPHERD

Folks come up with lots of reasons to justify their decisions. The goal of this article is to provide information that will help in making an informed decision. Having said that, I know of at least one person who chose to stick a 12V71 in an MCI (not one that had that engine as an OEM option), because someone told him it could not be done.

Let's set the stage for this article. The main audience will be bus owners with two-stroke engines. Many will have 6V92 or 8V71 engines. Some will have 4-71 or 6-71 engines. Those who are fortunate enough to own buses with later model four-stroke engines may enjoy reading the serialized article with the thought that they don't have to deal with the thought process, or the cost and labor of modifying their bus.

This article is based on a seminar that Sonnie Gray (Catskinner on the BCM board) and I developed for a couple of the Bussin' 200X rallies as well as one BusN USA rally. We had a ton of fun doing the seminars. I thought that our work should be published for folks who were not able to attend those rallies.

The seminars, and this article, are not intended to be a how-to-do presentation. Instead, the purpose is to pose a list of questions that should be addressed before a person plunges into this kind of project. The list of questions came from my extensive study of the conversion process (and engine modification technology) and my direct experience with my bus. I will give you what I think is a distillation of my research which involved a great deal of sorting good from the "marginal" information. However, I would like to approach



Figure 1: '54 Scenicruiser with a huge CAT 3408 and a 15-speed transmission.

this series of articles with the thought that it is one person's thoughts on the subject and that I want to encourage constructive responses from the very knowledgeable reader base (see contact information at the end of each serial presentation). I will consolidate that input as well as any additional thoughts and write a follow-up article.

Before we get started with the list, I would like to talk

about a really fun part of developing the engine conversion seminar: collecting photos of "unique" engine conversions. I have posted some of this collection at: <http://rvsafetysystems.com/engineconversion.htm>. One example is shown in Fig. 1. This is a '54 Scenicruiser with a huge CAT 3408 and a 15-speed transmission. I was able to talk to the owner when we were at Bonneville (note the salt) and he said he just "plays" with the huge fancy motorhomes.

Here is a list of the questions that I believe anyone thinking about improving their bus performance should consider. I will present this information in two segments over two issues of BCM.

October Issue

- Should I modify my two-stroke engine for more power?
- If I do a conversion, should I stay with a two-stroke and use a bigger engine or go to a four-stroke engine?
- If I do a conversion, should I use a mechanical or electronic engine?

- How do I select a donor engine?

November Issue

- Will a conversion increase my mileage? Is there a reasonable payback with increased mileage?
- What are the costs involved in an engine conversion/power upgrade?
- Should I think about doing the conversion myself?
- What systems will have to be fabricated?
- Why will I need to change my gearing for a four-stroke conversion?
- What about cooling problems?
- Will I have to do any special structural modifications.

Before we begin discussing my thoughts on the list of questions, let me give you a bit of my background. My bus is an 85 Eagle model 10 with a Series 60 and an Eaton AutoShift 10-speed truck transmission. Like a lot of folks, I looked in every engine compartment I could over many years of attending bus conversion rallies. I said to myself, how hard can an engine swap be? I have done several car engine swaps and they seemed pretty easy. As was the case with the cars, I did all of the work myself and I can tell you that it is a bit more complicated than most folks think. It is fairly simple to stick the engine in, but a lot of time consuming work has to be done to get everything hooked up and working properly.

Why did I choose to go to all that effort? My bus came with a mechanical 6V92 that was set at about 270 HP. We live in Colorado where we have to climb a lot of "hills" and the bus was simply underpowered. I did a lot of research and bought the parts to convert the 6V92 to 350 HP. Unfortunately, I did not get to drive it very much, as I had a head crack on it in spite of being very careful to avoid letting the coolant temperature exceed 210 degrees. I don't think the head crack was a result of the uprating. In any case, I simply did not want to spend the money to rebuild the 6V92 since it would have been very marginal in power (I pull a large service truck). I did a lot of thinking about my options and those thought processes are the foundation for this article. Now, let's get on with the show!

Should I modify my two-stroke engine for more power?

Virtually all of the 6&8V92 and 8V71 engines in buses were set for power significantly below what they are capable of producing. As I mentioned, mine was set for about 270 HP, while commercial versions are available at 350 HP and special applications can have much higher ratings. Modifying a mechanical two-stroke engine generally consists of changing the injectors, and turbo (or adding a turbo). In some cases,

the cam timing will need to be adjusted.

An electronic DDEC two-stroke engine can have the power increased by having Detroit Diesel re-program the engine computer. With all the emission regulations in place today, DDC is very reluctant to increase the HP on any engine. The change has to be approved by the main office and the program downloaded from the mainframe to the dealer computer. The dealer cannot make the change on his own.

A couple of folks on the Bus Conversion bulletin board have added turbochargers to their 4-71 and 8V71 engines. That does two things. Obviously, it increases the HP, but it also drastically improves performance at higher altitudes. Both applications that I am aware of, added a charge-air-cooler (a radiator to get rid of the heat in the compressed air). This is an excellent idea, even for an engine that already has a turbo.

The critical factor that will come up with any two-stroke modification is cooling. Two-stroke engines produce more heat than four-stroke engines and many bus applications are marginal to begin with. When you add power, you add heat and you must find a way to get rid of the heat. Modern radiator technology is much better than when most of our buses were built. If you modify your two-stroke, you should plan on having your radiator brought up to modern technology and/or increased in size.

The other critical factor is life reduction of the engine. Whenever you increase HP, you reduce the expected life of the engine. In the case of our buses, we put so few miles on that life reduction is not an issue if you stay within reasonable limits.

If I do a conversion, should I stay with a two-stroke or go to a four-stroke engine?

Certainly converting from one two-stroke engine to a larger two-stroke is easier than making a conversion to a four-stroke engine. An 8V92 is a popular swap for a marginal 6V92.

Lets' step back and look at the venerable two-stroke engine. It was first produced in 1938 for military equipment. The first engine was a 6-71. The 53 series started production in 1957 and the 92 series began production in 1974. The engine is still produced today according to some folks. They are still supported by DDC in terms of parts and available literature. With over 70 years of excellent track record, it is hard to argue against them. And they sound neat!

Some folks think that the two-stroke is a simple engine – comparing it to gasoline two-stroke engines. In truth, it is a fairly complex engine and one

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Engine Conversions [Continued]

that demands very special skills to properly tune up a mechanical injection engine (commonly called “running the rack”). The problem is that the technique to properly do the job is not easily described in manuals and the folks who can do the work are becoming fewer in number.

There is considerable discussion about two-stroke durability on the various boards. The general consensus is that the 92 series, with their wet cylinder liners, are not as robust as the 71 series. They are more prone to overheat failures (O-rings on the liners and cracked heads) than their predecessors.

Two-strokes are said to be a 300 to 500K mile engine before rebuild. However, they may require at least one bearing change during that period.

The biggest reliability issue with two-strokes involves overheating. They must be kept below 210 degrees. Many temperature gauges are not accurate. Some engines have shut-down protection, but mine did not prevent me from cracking a head. The margin for error is very small.

On the other hand, four-stroke engines are considered to be more robust. Some routinely go over one million miles before a rebuild is required. The biggest issue with four-stroke engines is that they are designed to operate at about 70% of the engine speed of a two-stroke. Two-strokes can run all day against the governor at 2100 RPM, while a four-stroke likes to cruise at 1400-1600 RPM. We will talk more about that later. The fact that the four-stroke is designed to operate at 30% lower RPM partially explains the difference in engine life. Obviously newer technology has improved engine life as well. We will talk about gearing options later in this article.

Almost all modern four-stroke engines are designed to have a charge air cooler between the turbo and the intake manifold. That will require a lot of plumbing fabrication and some provision for moving the air across the cooler. On the positive side, four-stroke engines generate much less heat. Often, original radiators in good condition are sufficient to cool the engine in spite of the fact that the four-stroke engine has significantly increased HP capacity. For example, my rebuilt 6V92 radiator provides plenty of cooling for my 470 HP Series 60.

There are a large number of modern four-stroke engines in salvage yards at what appear to be reasonable prices. From personal experience, I can tell you that you need to be very careful about selecting the engine for your conversion. More about that later.

There are two size categories of four-stroke engines that are candidates for our larger buses. The large four-stroke engines (e.g., Detroit Series 60/Cummins ISX/CAT N14) will require significant modifications to the bus including raising the floor to clear the tall engine. The mid-size engines (e.g. Cummins L10/M11/ISM and CAT equivalent) have great power and can be installed in many buses without raising the floor or extending the rear of the bus. There are many smaller diesel engines (e.g. IHC DT466, Cummins 5.9, etc.) that would not provide acceptable performance for 40 ft buses. I have seen them installed in smaller buses and they performed well.

If a person can find a way to provide proper gearing for the four-stroke, they are generally the best option. It is also the most costly option, as significantly more fabrication is required. We will talk more about cost later, but a professional four-stroke engine conversion often exceeds \$30-40k.

If I do a conversion should I use a mechanical or electronic engine?

Most modern four-stroke engines are electronic. However, you can still find mechanical Cummins and Caterpillar engines but they will be fairly old and may have lots of miles on them, or several rebuilds.

The argument for a mechanical engine is that they are easy to fix and any diesel mechanic can work on them. Some folks will argue that mechanics are not trained to work on electronic engines. That was perhaps true 10 years ago. Today all certified diesel mechanics are trained to work on electronic engines and have very sophisticated diagnostic equipment available to quickly diagnose an engine problem. Parts are readily available at any major diesel shop for both mechanical and electronic four-stroke engines.

The cost of parts for mechanical and electronic engines is roughly the same except for the injectors (almost twice as much for an electronic engine) and some of the electronic sensors. Today's electronic components are very robust. By definition, they are part of the emission system and have some very strong regulations/standards related to reliability and accuracy.

The beauty of an electronic engine is that it is designed to tell you what is wrong and has some very powerful protection software that prevents major engine damage for the most part. The prevailing thinking is that an electronic engine will give better fuel mileage (about 1 mile per gallon on a truck – a very significant percentage). Electronic engines have



fantastic cruise control capability and most come with Jake brakes.

For those of you who are data junkies (and who choose an electronic engine), you can create a very sophisticated electronic dash using your computer and SilverLeaf VMSPc (see Fig. 2). With this great tool, I very seldom use my old analog gauges. All of the data on the screen comes from the data port which is reading the very accurate engine sensors. You no longer have to deal

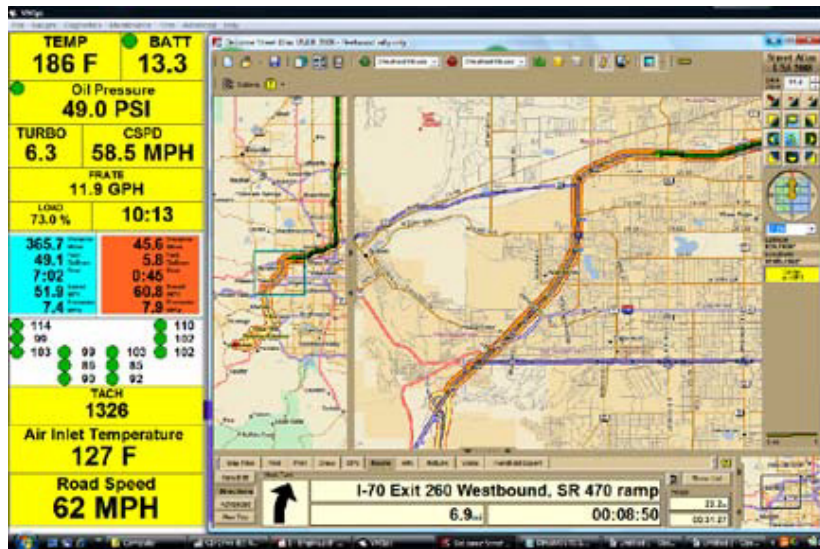


Figure 2: Silverleaf dash.

with analog gauges of suspect accuracy.

Switching from a mechanical two-stroke engine to an electronic engine is a challenge. First, a person has to make sure that they get all of the related components from the donor vehicle. Next, a cable of bundled wires must be fabricated. These cables contain all of the data and control wires. My DDEC III/IV system has 21 wires and the AutoShift has 11 wires (I list the harness information for both the engine

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and transmission cables at: <http://www.rvsafetysystems.com/busproject7.htm>). It all sounds very complicated, but a person does not have to be an electrical engineer to do the work. It is an absolute must to have detailed wiring diagrams. Most engine manufacturers have great manuals. For the Detroit Diesel Series 60, the bible is the Application and Installation manual. This is a manual written for the OEM who designs their equipment for the use of a Series 60 engine. Oftentimes these manuals are available on eBay.

Many truck donor vehicles will have a Deutsch connectors at the firewall. You can purchase matching Deutsch connectors for manufacturing the cable that runs the length of the bus. I have some pictures of the connectors and the cable information on my bus project pages (<http://www.rvsafetysystems.com/busproject4.htm>)

As you can probably tell, I favor the electronic engine. Sonnie prefers the mechanical engine approach. We had a lot of fun with that subject at the seminars.

How do I select a donor engine?

I have been working on this article over a period of

several months. My first outline did not contain this section. However, I have been forced to give a great deal of thought about how one goes about selecting a donor engine in recent months. Here, we are talking about both two-stroke and four-stroke engines.

Some of you have followed the saga of my Series 60 engine "failure" on the Bus Conversion Bulletin Board. If you have, you know the pain and suffering one goes through when you have to rebuild/replace an engine. It is a huge expense and involves lots of stress and a big pile of money.

So, what can we learn from my experience?

First of all, buying a used engine is really rolling the dice. Most donor engines do not have documented records. Even if they did, stuff can still happen

Let's take a look at my thought process and see where it went wrong. When I decided to install a Series 60, I did quite a bit of "research." Just about everybody I talked to and everything I read told me they were a tremendously reliable "million mile" engine. I could only find one local engine and it had



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670K miles. I checked a fairly large geographical area and could still not find anything with less miles. I was nervous, but everything I read suggested that I should get another 250-300K miles and that is plenty for an RV. I should note that I received an oil analysis and had new bearings “rolled” in to be on the safe side. I also replaced “consumable” items like the turbo, water pump, etc.

I got 53K miles out of my used engine and now, I am paying the price for the roll of the dice. My mode of failure was seating of the liners down into the block (due to vibration and erosion). This caused a loss of sealing of the head gasket which led to several other problems. I suspect that my 1996 engine did not receive good maintenance in the last few years of operation before I bought it. I suspect that part of the problem was use of incorrect antifreeze (see my September 2009 *Bus Conversion Magazine* article).

Once I developed the engine problem, the real truth about modern diesel engine reliability started to reveal itself. Sure, some modern four-stroke engines go over 1 million miles without a problem. In my previous life, I worked a great deal with statistics (even wrote an SAE paper on the subject) and you would think that I should have known that almost EVERYTHING on this planet has a statistical life distribution (loosely referred to as a “bell curve”). A good example is human life (huge spread of age to death). Those million mile engines are on the far end of the “bell curve” and my engine seems to have failed at about the median life. If you want a real eye opener do a search for used diesel engines. One site that someone referred me to was: <http://thetruckparts.com/enginesforsale.aspx>. If you search on any given engine you will see many with some sort of major engine problem in the 700-1000K mile range.

Series 60 engines are a popular conversion engine. As I began to learn more about their failure pattern, I found that they often develop the liner problem and also have a major issue with the “bull gear” that drives the cam and all of the accessories. DDC suggests re-

placing the gear at 700K miles. If the bull gear fails, it will virtually destroy the engine.

DDC is not unique in the statistics of engine failure. Many folks have used Cummins M11 /ISM engines for their conversions. At least one reader has done a CAT conversion. These engines do not defy statistics any more than any other product.

Now that I have you scared to death about selecting an engine, what can you do put the odds in your favor when you buy an engine? First and foremost, buy your engine from a reputable vendor that comes recommended by satisfied customers. Buy an engine that had documented low mileage. In the case of Series 60, I would not buy an engine that had over 500K miles (since new or since receiving an acceptable rebuild). In the case of the Cummins M11 /ISM, most experts suggest an engine with less than 250-300K miles. Engines with low miles will be more expensive, but that could be good economics. A different approach that I like, is to buy a high mileage engine and have it rebuilt. Then you know that you have a reliable engine. You pay more up front, but the peace of mind is priceless. Buying an engine from an individual who has good maintenance documentation is another approach.

Electronic engines store the mileage and other data on the ECM. At the very least, I would have the ECM read by someone with the proper equipment. Even that can be deceiving, as the ECM could have been replaced. When that occurs, the mileage starts from zero and all history is lost.

When it comes to two-stroke donor engines, all bets are off. First, they have a shorter “average” life than a four-stroke. They have more prevalent failure modes (cracked heads, liner “O” Ring failures, etc). In addition, they are older engines and many have been rebuilt at least once.

Some suggest having an oil sample taken from the donor engine. My engine had a good oil sample report. However, my failure mode was not revealed in the oil analysis. Further, most experts suggest that oil

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Jim Shepherd and Sonnie Gray have conducted several engine conversion presentations at various bus rallies. These presentations are typically split into two sections:

- a. Presentation of their thoughts*
- b. Round table discussion*

We would like to treat this article the same way. Consider this series of articles, the presentation. After you have read this month's article, think about the opportunity for a round table discussion. Once you have reflected and digested, share your thoughts with Jim. He plans to consolidate the feedback received into a follow up article. Jim can be contacted via Email: jim@rvsafetysystems.com.

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sample testing is really a “trend” analysis where you are looking for significant changes between samples.

Finally, let me touch on “rebuilt” engines. The quality of the parts and workmanship varies all over the map. There are hole-in-the-wall shops that do great work, but that tends to be the exception in my opinion. There are widely varying degrees of rebuilding. It runs the gamut from sticking new rings and bearings in, to a complete rebuild with new liners and pistons and all parts replaced as needed. Again, saving a few dollars with a marginal rebuilder may not make long-term sense. The quality control process of the DDC authorized dealer/service company is hard to beat. The same would be true for authorized CAT and Cummins engines dealer/service organizations. *Bus Conversion Magazine* has at least one advertiser who has a virtually spotless record from all reports. These are the shops that should be primary on the list of places to take an engine for rebuild.

Yes, I admit that there are probably a few “cream puff” engines lurking around, but they are few and far between. Take it from a voice of experience!



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