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Innovation in Future Truck Cab Designs *An Exploration of New Possibilities*

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INTRODUCTION

This paper is a result of a "freewheeling" consideration of changes in the layout of various cab components and driver positioning and the effect of such changes on safety and operations. It is meant to provoke discussion and encourage innovation. The authors do not necessarily advocate any particular design or approach, but they do advocate spirited debate and serious consideration of the value of these changes to cab design. This challenge to the traditional cab layout allows the truck designer more flexibility to engineer out some inherent limitations of today's chassis and cabs, limitations on serviceability, maintainability, ergonomics, visibility, driver productivity, cost of ownership, and safety.

Current heavy-duty tractor cab designs have reached new plateaus of efficiency, safety and driver convenience. In the quest for continuous improvement it is timely to consider the next plateaus. Possible approaches are con-

sidered that flow from simple changes, such as repositioning the radiator and other cab components, and which open up revolutionary design possibilities. These possibilities can measurably increase fuel economy, enhance productivity and occupant safety.

CHANGES IN LOCATION OF CAB/CHASSIS COMPONENTS

Repositioning the Radiator

Traditional tractor design places the radiator at the forward-most position in the chassis. This position allows simple fan drives and maximum airflow through the heat exchange units - radiator, aftercoolers and air conditioning condensers, but places these units "in harms way," and requires a blunt vehicle nose to house it, which produces aerodynamic drag. The current radiator position, while more crash-damage resistant than it appears, is still in a vulnerable position and serious damage to the radiator will cause the truck to go down and

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perhaps cause the owner to miss a drop. It also is vulnerable to flying debris. Not only can debris damage the unit, but bugs and ice buildup can reduce airflow. With the radiator out front, directly in the path of this “dirty” air stream there is no opportunity for the designer to mitigate these effects.

In its most forward and central location the radiator dumps heat at the driver. Without any underhood or undercab airflow management the only path for the rejected heat is directly to the rear. This increases the environmental stress on drivers and necessitates increased cab cooling capability.

The traditional position reduces accessibility to both the heat exchange units and components on the front of the engine, such as fan drives, belt drives, water pumps, alternators, air conditioning compressors and numerous engine seals, and covers. In addition, some major maintenance functions involving the camshaft or front cover require radiator removal.

Alternative Radiator Locations —Alternative locations have been made to work in buses and specialized chassis configurations, thus there should be no problem making them work in the relatively simpler tractors. The question is: what are the alternative locations? We propose rear, and split side mounting. Rear mounting is a position at the rear of the cab. Split side mounting is a position in which the cooling /heat exchange requirement is halved and each half is met by a radiator installation on each side of the cab. That is instead of a single large radiator, two smaller ones are used. This installation is especially attractive when combined with the center driving position, discussed later in this paper. These alternative locations can provide designers more flexibility and can lead to improved access to radiators and engine components; lowered cab noses for reduced aerodynamic drag, leading to better fuel economy;

and better forward visibility for drivers, because the hood can be more sharply sloped.

Reduction in Size of Radiators — Evaluation of engine cooling requirements should consider the impact of low heat rejection (LHR) engines. At one time it was thought that a so-called adiabatic engine could be developed, which would not need a cooling system. Over time that possibility has eluded researchers, but the LHR engine still remains a serious possibility. Thus potential future reduced cooling requirements may make the implementation of alternative radiator locations much more feasible than it would first appear. Another development that can reduce radiator size (and weight) is the use of nanofluids as the heat transfer medium¹.

Water/ethylene glycol mixtures have relatively low thermal conductivity and specific heat. Nanofluids are a new class of heat transfer fluids that suspend nanometer sized metallic particles in conventional heat transfer fluids. (Metals have thermal conductivity values that are many times greater than the fluids themselves). Recent measurements show as much as an 80 percent improvement in heat transfer coefficient with a dispersion of less than 3 percent by volume of alumina nanoparticles.

Repositioning the Door

All trucks require some amount of climbing into the driver’s position. This exposes the driver to a number of climbing components that are less than ideal for their purpose, which is to get the driver into his seat. Statistics compiled by the American Trucking Associations Foundation, in 1994, indicate that slips and falls account for 22 percent of all injury claims by drivers and 18 percent of claims by maintenance personnel; and 40 percent of all injuries, which are half of all workers’ compensation claims, are due to slips, falls and lifting². The design compromises required to allow entry and exit into the cab are the result of traditional cab door location. A possible ap-

proach to ameliorate the situation is to provide disappearing stairs, once used by Ford Motor Company in their Super Transport Truck of 1964³ and most recently by Freightliner in their Argosy. However, retractable stairs may not deal well with ice and snow buildup and raise issues of reliability, maintainability, and cost of repair due crash damage. The possible inability to function, when it is needed most, would offset any advantage provided in normal operations. Basically, retractable steps/stairs have to be considered because of the location of the doors.

Alternative Door Positions—Entry could be by a door at the right rear of the passenger side, eliminating the door on the driver's side, or at the rear of the cab (perhaps a sliding door), or at the passenger side ala a passenger bus. These positions would eliminate the need for retractable steps/stairs and for doors opening into traffic. For on-highway use there is little need for a driver to have ready entry and exit provided by a door on his immediate left. The door on the driver's left seems to be necessary for pickup and delivery vehicles, but the road tractor does not need to share this particular feature in order to fulfill its function. Designers should question the automatic provision of two doors.

Today's doors are complex and expensive, and will become more so if side impact protection is ever considered. The hole in the in the cab structure for the door weakens the cab structure, especially if a "stressed skin" design is contemplated. The window in the door is restricted by door size and limits visibility.



Figure 1

Current door placement involves a large vertical climb on the exterior of the vehicle. Figures 1 through 4 show a driver entering a conventional tractor. This driver is 5'6" tall. The COE configuration presents a more severe situation with a near vertical climb above the front tire. Snow, ice and rain make the situation worse, contributing in large measure to the statistics of Reference 2. Repositioning the door allows the possibility of making entry and exit easier and better ergonomically. Compare stepping up a set of steps to enter a door in the rear of the cab, suggested by Figure 5, to the twisting and turning now required. The right front bus style entry would place the door just ahead of or just behind the front wheel. This location and type of entry could be closer to ground level and protected from the elements. Potential payoffs would accrue from reduced injuries



Figure 2



Figure 3



Figure 2

and workmens' compensation claims.

Repositioning the Sleeper Berth

The current orientation of the sleeper berth is guaranteed to work against a good sleep in a moving vehicle. Longitudinal accelerations and decelerations roll the occupant from side to side, much like the occupant of a first class sleeper on an AMTRAK train. In addition, restraint of the sleeper occupant is a difficult problem, addressed by measures that also work against a comfortable sleep. Orienting the bunk in a fore and aft direction would reduce the sensation felt due to longitudinal accelerations. The tradeoff is that it would subject the occupant to lateral accelerations, but these seem to be less severe.



Figure 5

CHANGES INVOLVING DRIVERS

There are several changes that could be made that affect drivers. These involve the drivers' location in the cab, and elimination of the steering wheel and instrument panel.

Driver's Location in the Cab

Investigation should be made into the feasibility of locating the driver in the center of the cab. This is potentially a safer, location because there would be more survival space on each side of the driver. Throughout this paper the implied question is "why are doing things the way we are?" Why did the present location become standard? Fiat has investigated a driver in the center for a concept van. Our contention is that this location is the more logical, provides equal indirect vision to each side, and superior direct vision.

Eliminate the Steering Wheel

It can be argued that the steering wheel is an anachronism, a sort of more efficient tiller. It works through weighty linkages, a shaft and usually works with a power steering pump—a maintenance item. Worse, it is a cause of injury. Clarke, in Reference 4, reports that the source of most injury among drivers of combination unit trucks involved in accidents was the steering wheel—67 percent of fatally injured drivers contacted the steering wheel. Although introduction of three-point seat belt greatly reduces the likelihood of driver contact with the steering wheel, it still protrudes into the drivers' survival space, (see Figure 6).

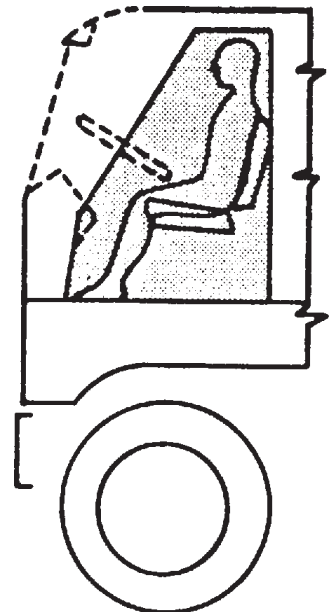


Figure 6

Steering wheels could be replaced by "side controllers", an aircraft type stick at the drivers side. These are used in passenger aircraft (Airbus series) and SMB is investigating them as part of the development of an active steering system⁵. The current steering assembly would be replaced by a "steer by wire" system. The major payoff would be enhanced safety, not only because of elimination of injuries from hitting the steering wheel, but also from increased driver comfort (should equal less fatigue).

Eliminate the Instrument Panel

It exists mainly to provide a place for instruments to communicate information to drivers and for drivers to "instruct" the truck via switches (e.g. turn on headlights). The task of communicating information to the driver can be re-

duced to those things required by regulation (e.g. speedometer) and “management by exception” messages. Switches, radios, cell phones etc. can be incorporated in the side controller housing next to the driver, or in a housing on the other side of the driver. In essence, what used to be in front of the driver, and what he had to reach for (because of the steering wheel) is now next to him, literally at his finger tips. In addition to safety benefits clearing the area in front of the driver would increase maintainability by providing easier access windshield wiper systems, and ultimately be less costly to manufacture and maintain.

OTHER CONSIDERATIONS

Any consideration of future cab designs must take into account innovation in engines and fuel systems.

Possible Future Engines

These include gas turbines, combinations of gas turbines and diesel engines (giesels) and horizontally opposed engines.

Gas Turbines—A number of companies and government agencies have experimented with gas turbines since at least the 1950s. Garrett tested their GT 601 gas turbine in a Mack 795S in 1977-1978⁶. Detroit Diesel Allison conducted a field evaluation of two models, the GT404

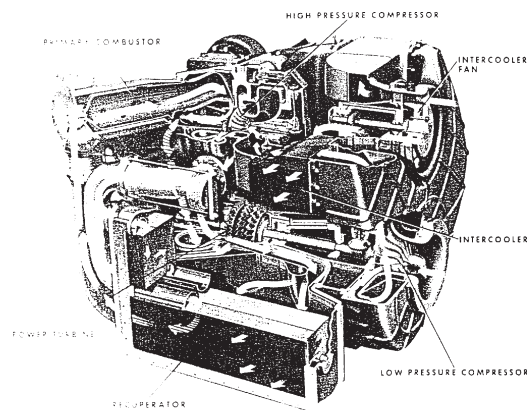


Figure 7

and 505 from 1974 to late 1977. Consolidated Freightways, Greyhound, Ruan Transportation, Terminal Transport, GM Truck and Coach and Freightliner participated⁷. Ford used a supercharged gas turbine, the 705, in their Super Highway Truck³. It was 49" long by 44" wide and 38" high. It is shown in Figure 7, and its installation is shown in Figure 8. This truck went on a 5,500 mile national tour in 1964. In 1979 a DDA GT404 powered bus went into service with Greyhound. The Department of Energy has long supported the development of high efficiency, multi-fuel, low polluting gas turbines and continues to do so.

Gas Turbine Combinations—There is a combined gas turbine/diesel engine under development called the “giesel” (gas turbine and

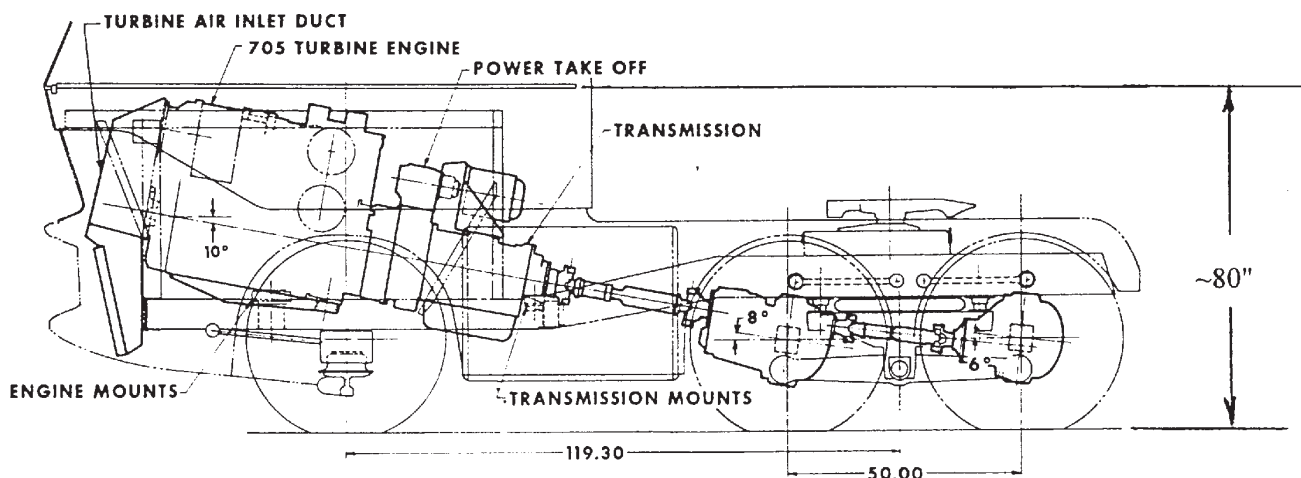


Figure 8

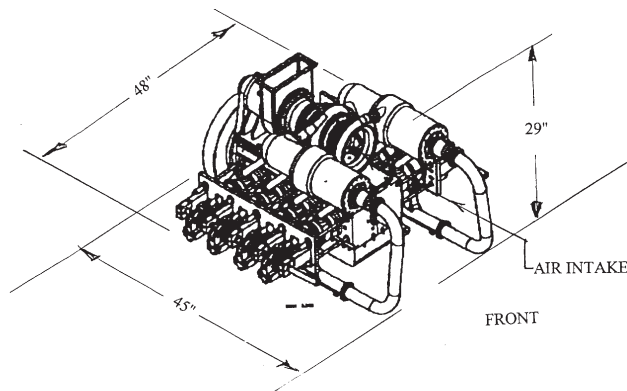


Figure 9

diesel), see Figure 9. This engine is much lighter than current diesels, weighing 400 pounds while delivering 600 hp. This 0.661b/hp compared to current diesels weighing 5 or more lb/hp. This combination has 20-30 percent lower fuel consumption, or a BSFC of 0.25. It is in the pre-prototype stage and is being funded by the U.S. Army⁹. Note the small height of the giesel, comparable to pure turbine engines.

Horizontally Opposed Engines—These engines, commonly used in light aircraft and in the original Volkswagen “Beetle,” have opposed cylinders resulting in a flat or pancake engine configuration. The giesel utilizes this configuration for the diesel part of the combination. This configuration has a number of advantages: the doghouse in COEs would be eliminated, overall space required for engines would be reduced, and maintainability could be significantly improved.

Improved Maintainability With Future Engines—The reduced size and weight of future engines, and the repositioning of the radiator would allow construction of the engine-transmission on a readily removable pallet. Typically, the major down time experienced by a tractor is either power or chassis/cab related. By giving the fleet operator the ability to swap with relative ease among power train units additional utilization could be achieved. This slide out pallet would also vastly improve accessibility to powertrain components and the

ergonomics of maintenance. In the 1980s, the then Leaseway Corp. constructed a prototype optimized stepvan with a drivetrain pallet that slid out the front of the van. This configuration was a technical success, improving productivity and maintainability, but become controversial with union drivers and was abandoned¹⁰. The Ford Super Transport³ had a pallet on which the engine and transmission were slid out of the cab.

Impact of Fuel Tank Research

Conformable tanks present the possibility of more protected and possibly larger capacity fuel tanks for tractors. These tanks could be placed between the frame rails or wherever space is available to give tractor designers more flexibility to shape the cab for better aerodynamics and of course reduce the risk of post crash fires. This approach also promises a single tank, with its capacity equal to the dual tanks now used, eliminating the relatively complicated plumbing needed for dual tanks.

DESIGN SYNTHESIS

Four conceptual designs incorporating changes in the position of various components, driver location and possible future engines are shown in Figures 10-14. These are rear entry, center driver position, side controller in lieu of a steering wheel, no instrument panel, repositioned radiator and a horizontally opposed diesel /turbine engine, in a COE layout, see Figure 10; and a conventional cab layout, see Figure 11. Figure 12 shows alternative double sleeper bunks with the space envelope of an AMTRAK double slumber coach superimposed. Figure 13 shows the giesel engine in the rear of the cab and the door on the passenger side with a bus/motor home style entry. Figure 14 shows another version of the conventional cab layout. Note the much greater visibility over the hood. Conformable fuel tanks are assumed in each design. There are many variations that can be devised using various combinations of the elements discussed in this paper.

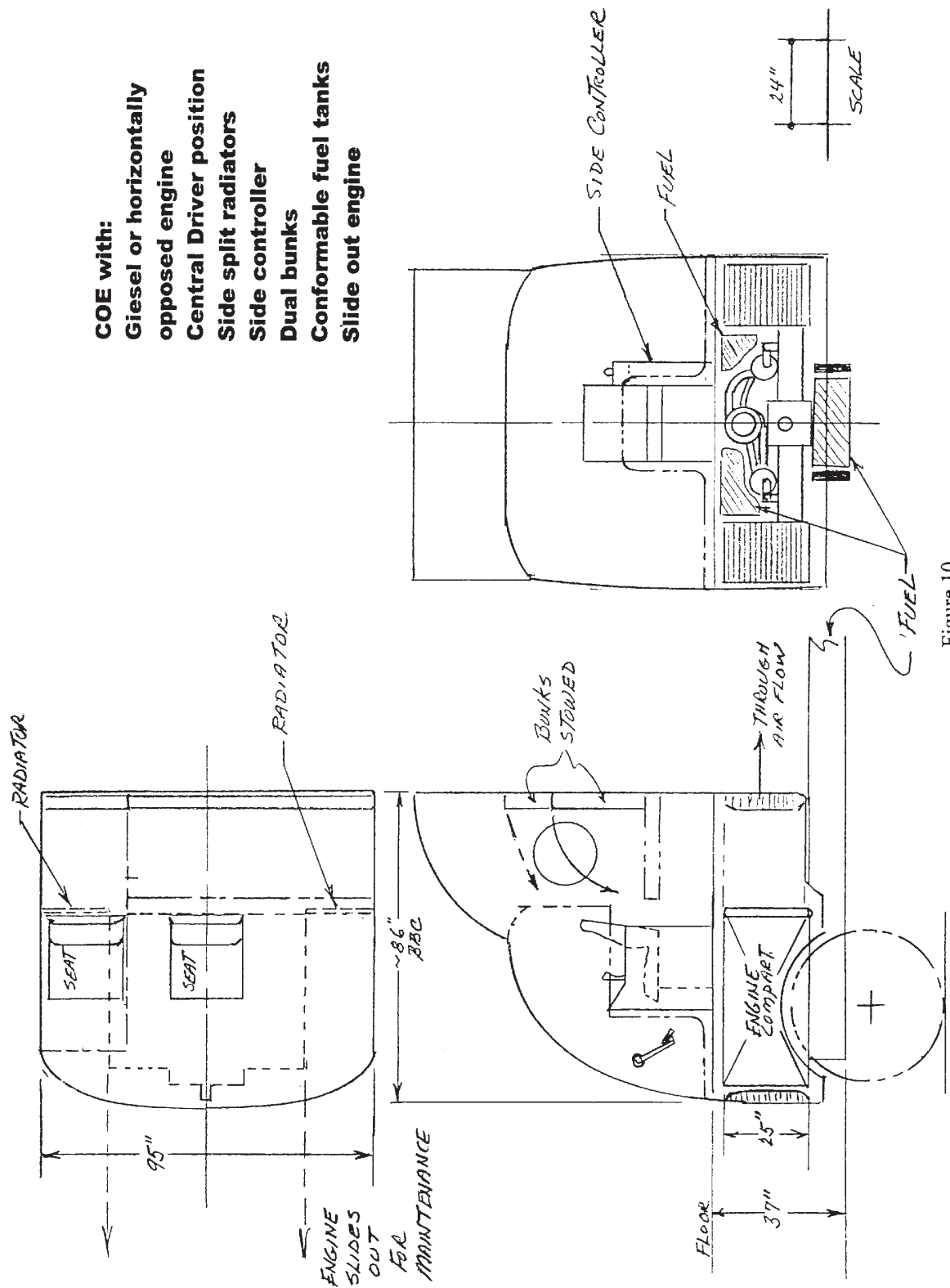
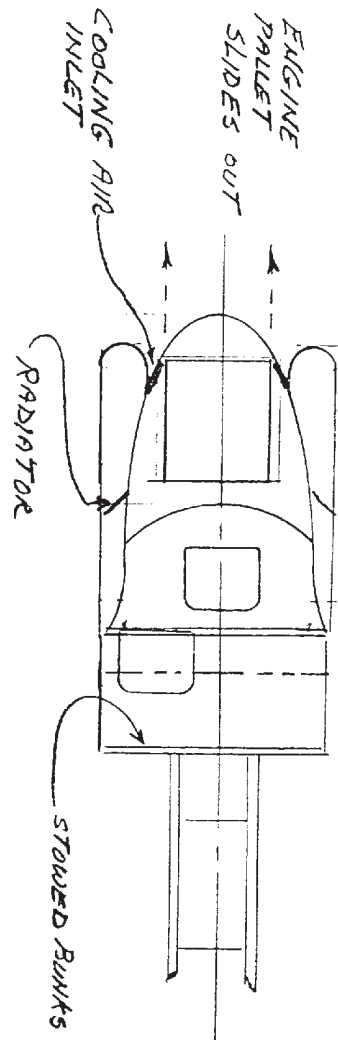


Figure 10

Figure 10



**Conventional with:
Giesel or horizontally
opposed engine
Central Driver Position
Split radiators**

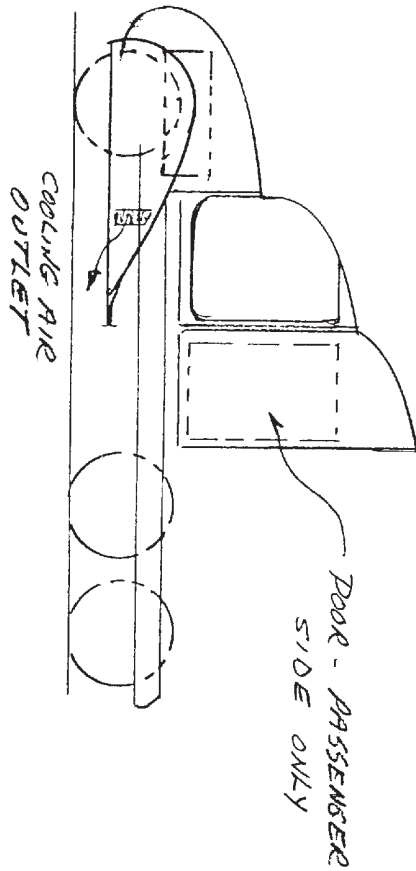


Figure 11

Figure 11

Amtrak Sleeper Accommodations The Roomette, Single Slumbercoach, and the Double Slumbercoach, Compared to Space Available in Truck Cabs

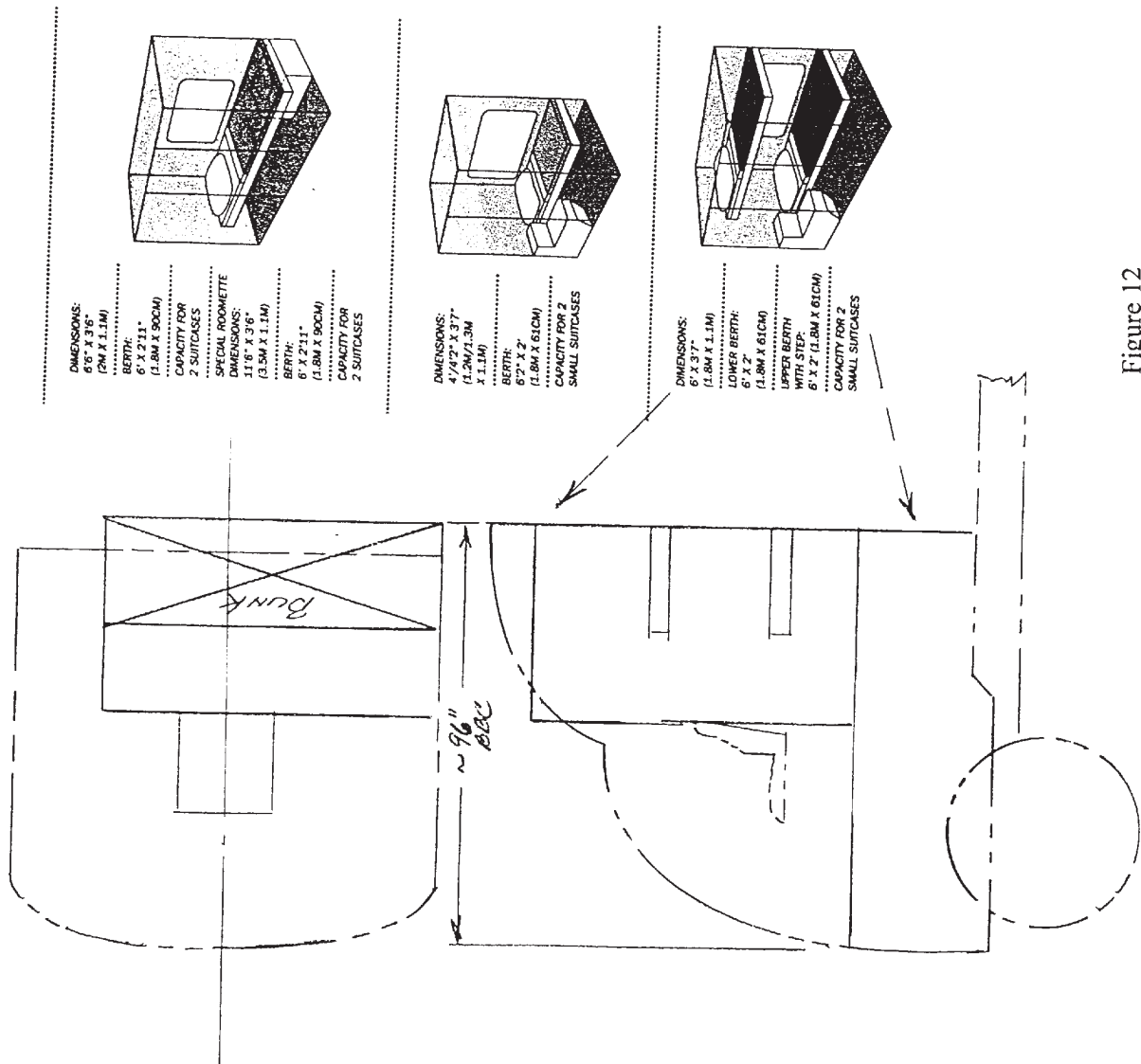
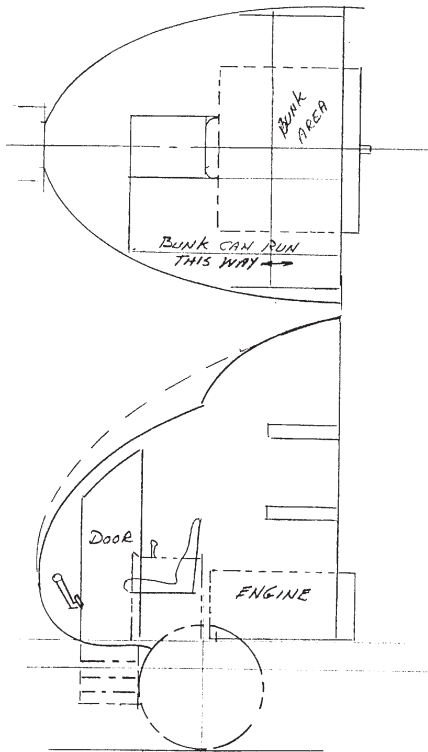


Figure 12

Figure 12



Rear engine version of COE
Central driver position
Door on passenger side with
bus/motor home style entry

Figure 13

Figure 13

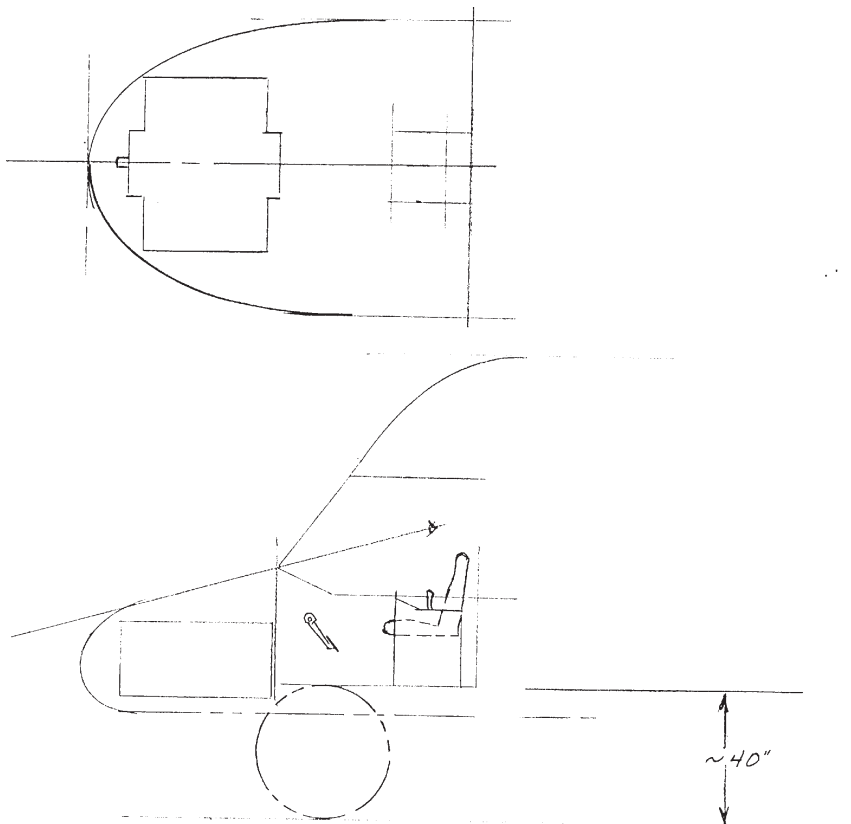


Figure 13

CONCLUSIONS

It would appear that innovations in future engines and heat exchange media are the keys to setting designers loose to rethink the basics of cab design.

Questioning the current placement of drivers, doors and radiators could lead to further innovations in cab design, which could improve fuel economy and safety. Moreover, the traditional cabover and conventional layouts might merge into a single configuration. The terms “cabover” and “conventional” could disappear from the industry.

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