United States
Department of
Agriculture

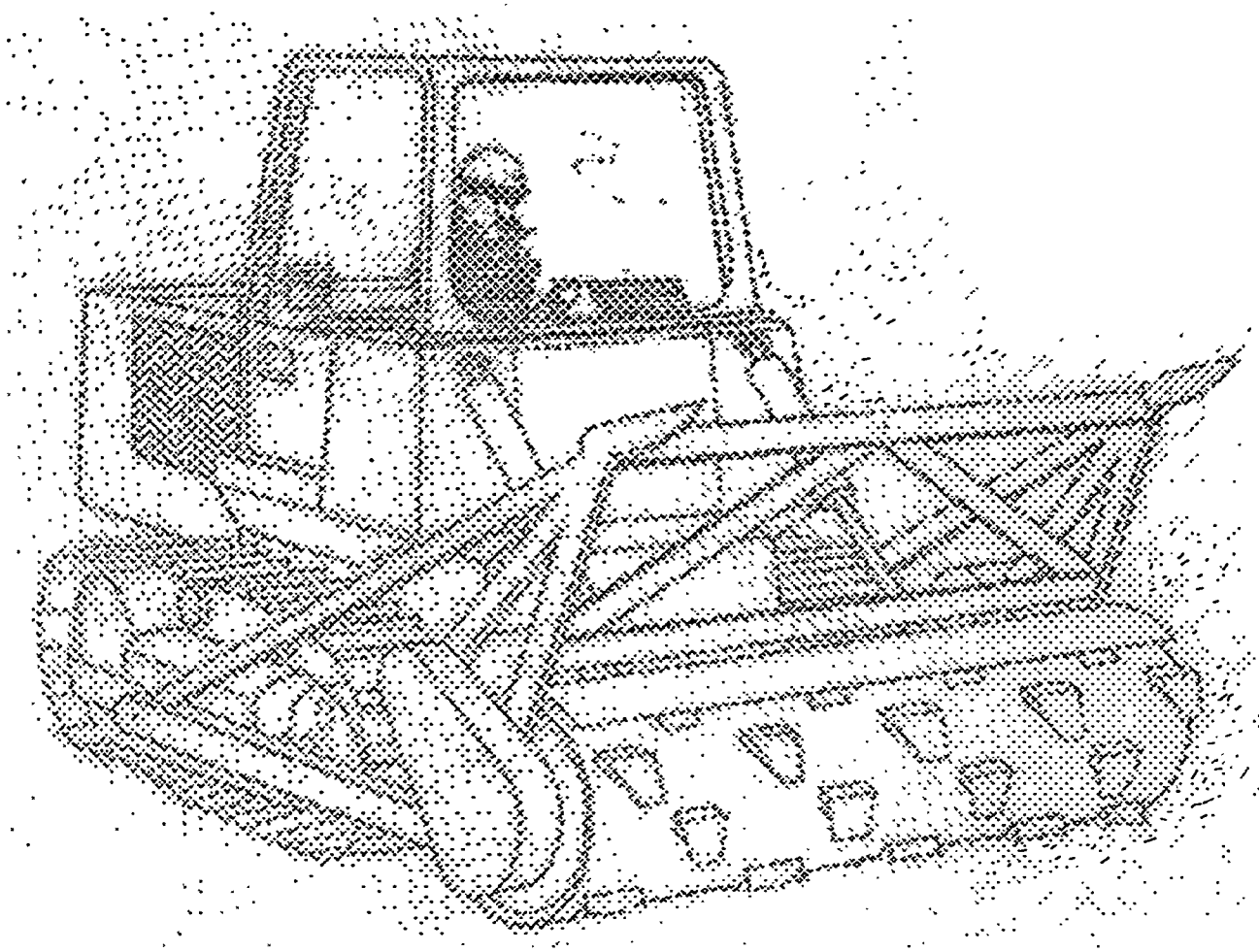
Forest Service

Technology &
Development
Center

2400—Timber Management
March 1991
9124 1204

Precommercial Thinning and Slash Treatment Machine—

A Prospectus



Precommercial Thinning and Slash Treatment Machine—
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TE01I25
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INTRODUCTION

The USDA Forest Service has long been interested in effective equipment that can precommercial thin young timber stands, release established plantations from brush competition, and treat the resulting slash. A third desired employment of this type of equipment is the treatment of logging slash. Over the years the Forest Service has purchased, contracted, used, tested, and reported on heavy-duty precommercial thinning and logging slash treatment equipment. Most of this equipment has functioned less than satisfactory. Much of this dissatisfaction arises from the equipment limitations, the generally slow production rates, and high cost per acre of doing the job with the available equipment.

This high cost results from the fact that much of the available equipment is designed to leave a treated area looking like a park. These pieces of equipment shred the material very fine and have a low production rate. Thus, the equipment's slowness, or low production rate, and only being able to divide the fuel much finer than required to meet Forest Service objectives drives up costs—as does the general unreliability of these units.

The short-range objective of the Forest Service in treating precommercial thinning and logging slash is to reduce the fire hazard by dividing and redistributing the small diameter fuel and bringing it closer to the ground resulting in increased fuel moisture, which slows fire spread and heat output. This reduces the rate of fire spread and makes fire control easier. Longer range objectives are to reduce the fire hazard even more, to have the material act as ground cover for protection from the sun, to reduce soil erosion, and meet visual quality objectives. Also, over time, the material decays, returning nutrients to the soil.

A further objective is to create planting sites for natural and artificial regeneration. Here again, getting the material close to the ground aids greatly to accomplish this objective. A possible goal for an area is that, after slash treatment, it should have 2 by 4 or 4 by 4 inch pieces, 2 to 6 feet long—and all the fines (needles and small branches)—on the ground. With the material on or near the ground, the fire hazard is greatly reduced and the material decays faster.

CURRENT EQUIPMENT SELECTION CRITERIA

Since current available slash treatment machines are not meeting the objectives of the Forest Service very well, let's consider a machine that would. In the reporting of equipment available, a selection criteria has been developed and published in the San Dimas Technology and Development Center (SDTDC) document "Field Equipment for Precommercial Thinning and Slash Treatment—Update" (January 1991). This field selection criteria lists nine items which should be considered in selecting and operating precommercial thinning, conifer release, and slash treatment equipment:

1. *Vertical or horizontal shaft reduction head*
2. *Fixed or free-swinging cutters*
3. *Integral, self-propelled, special-design, attachment, or towed machine*
4. *Wheeled or tracked machine*
5. *Single engine with an effective transmission or an auxiliary engine to drive the slash treatment tool*
6. *Operator's position and visibility*
7. *Availability, reliability, and maintainability*
8. *Maneuverability and agility*
9. *Safety.*

SELECTION CRITERIA DISCUSSION

By considering each of these nine criteria, a concept for a desirable machine, which can do precommercial thinning, conifer release, and treat precommercial tinning and logging slash, can be developed.

1. Vertical or Horizontal Shaft Reduction Head

A vertical-shaft reduction head machine has its main shaft in a vertical position (like that in a rotary lawn mower), and a horizontal-shaft reduction head machine has its main shaft horizontal to the ground (like that of a reel lawn mower). The horizontal-shaft reduction head machine has some major advantages over the vertical-shaft reduction one; these are:

A. Capable of cutting close to the ground
B. Can be a closer coupled machine
C. Can have very good operator visibility.

Also from field observations, horizontal-shaft machines appear to be safer because they do not tend to throw material in all directions. Thrown material is not only a serious safety hazard to personnel, but also can damage leave trees. Dust has been a problem with horizontal-shaft machines, but not as much of a problem as with vertical-shaft machines. Further, if the horizontal-shaft machine is operated just above ground level, the dust problem will be greatly reduced. The dust problem can also be greatly reduced by scheduling work during periods of moderate to high ground moisture (such as during and after spring breakup and after a rain) and avoiding periods of very low ground moisture. Therefore, for these reasons and other considerations in machine design (e.g., a compressed configuration), a horizontal-shaft reduction head is desirable for a slash treatment machine to meet Forest Service objectives.

2. Fixed or Free-swinging Cutters

Reduction heads can have cutters (teeth, blades, or flails) that are fixed or free swinging. Most of the available equipment have free-swinging flails which, in general, shred slash material very fine. This is OK, but not necessary. Fixed-tooth reduction heads generally run

slower, require less power, can cut down very large trees, and can reduce very large stumps to ground level or below. Because reduction heads with fixed-tooth cutters generally turn slower than reduction heads with free-swinging cutters, reduction heads with fixed-tooth cutters do not tend to throw material very far. They also create less dust, and dust can be a major problem that severely reduces production. Reduction heads with fixed-tooth cutters also tend to breakup material into large chunks. This meets the Forest Service objective of reducing the fire hazard by dividing the fuel and bringing it closer to the ground to reduce the rate of fire spread and make fire control easier.

It has been found that with good operator position, good visibility, and some operator care and concern, rocks can be avoided well enough so as not to be a serious problem most of the time. Fixed-tooth machines have been designed to handle some rock without much problem. The type of material that a fixed-tooth machine can handle is anything that can be cut with an ax. Field reports and personal observation confirm that fixed-tooth machines are working successfully. For these reasons, a fixed-tooth reduction head machine is desirable for a slash treatment machine to meet Forest Service objectives in precommercial thinning and slash treatment.

3. Integral, Self-propelled, Special-design, Attachment, or Towed Machine

Integral, self-propelled, or special-design machines usually possess more desirable features (such as the use of a single engine, good operator position, high maneuverability and agility, and enhanced safety) then can be obtained from an attachment to an existing prime mover or a towed machine. Also, almost all currently available precommercial thinning and slash treatment equipment is of the integral, self-propelled, special-design type. Therefore, an integral, self-propelled, special-design carrier for a slash treatment machine is desirable to meet the Forest Service objectives.

4. Wheeled or Tracked Machine

Wheeled, or rubber-tired, vehicles exert more ground pressure than tracked vehicles and, generally, cannot operate on as steep a slope as a tracked vehicle. The maximum slope for wheeled vehicles is in the range of 15 to 20 percent; for tracked vehicles, 30 to 35 percent. Wheeled vehicles are usually not as maneuverable as tracked vehicles, since they cannot turn in their own length. Also, wheeled vehicles generally have a higher center of gravity than tracked vehicles.

Tracked vehicles can generally be used under more severe conditions than wheeled vehicles. However; if an area lends itself to wheeled-vehicle operation, the use of a wheeled vehicle is usually more economical. Tractor crushing is a current method used to breakup slash and reduce aerial fuels by using the tracks of a crawler tractor to break and crush slash. For these reasons, a tracked machine is desirable for a slash treatment machine to meet Forest Service objectives in precommercial thinning and logging slash treatment.

5. Single Engine with an Effective Transmission or an Auxiliary Engine to Drive the Slash Treatment Tool

A well-designed prime mover for precommercial thinning, conifer release, and slash treatment should have a single engine with adequate power to both propel the vehicle and drive the slash treatment tool. The use of a single engine for both functions keeps the weight and size of the vehicle to a minimum, while providing maximum power to perform either function. When a single engine is used, the vehicle must have a transmission system that can deliver almost full power to the slash treatment tool while propelling the vehicle at the required operating speed. The required operating speed can be stopped, near zero (most difficult), or up to 4 mph. Also the transmission must be able to propel the vehicle at full speed. This may require that full (or almost full) power be directed to driving the vehicle.

A hydrostatic transmission is the type of transmission now most often used because of its ability to accomplish the above drive requirements. A hydrostatic transmission usually incorporates a variable-displacement hydraulic pump driving a fixed-displacement hydraulic motor in a closed-loop hydraulic system, with some designs operating at up to 6,000 psi. A variable-displacement hydraulic motor is sometimes used to gain a wider drive ratio without requiring gear changes.

Also, speed can be easily changed with a hydrostatic transmission. This allows the operator to "push production" by moving as fast as the machine can handle the material being treated. If, for a short distance, there is no material present that requires treatment, travel speed can be increased to cover the distance as rapidly as possible. The result is increased production. When a single engine is used, a hydrostatic transmission for propelling the vehicle enables the engine to run at maximum rpm. This allows almost full engine power to be delivered to the slash treatment tool while the vehicle travel speed varies from zero to the maximum.

For all the reasons just given, a single engine driving a hydrostatic transmission is desirable for a slash treatment machine to meet Forest Service objectives.

6. Operator's Position and Visibility

A slash treatment machine should have high production rates to meet Forest Service objectives and, therefore, must have the best possible operator's position. This means the best view of the immediate work area possible and an enclosed and air conditioned cab. The best view of the work area is a high, forward position for

the operator. To protect the operator from dust and heat, the operator's position must be enclosed and air conditioned.

7. Availability, Reliability, and Maintainability

Availability, in a general sense, is the degree to which a machine is in an operable state when called upon to perform. Specifically, it is the percent of total scheduled time the machine is able to operate; i.e., the percent of time that the machine is not broken down. Availability is a function of how reliable its components are, and how easy it is to repair a failed machine.

Reliability is the probability that a machine will perform its intended function for a specified interval of time under stated conditions; i.e., how often the machine breaks down, or mean time between failures.

Maintainability is that characteristic of design expressed as the probability that a machine can be repaired within a given period of time; i.e., how long it will take to fix a broken machine. How easy and how much time to repair a failed machine determines a machine's maintainability.

In the severe operating environment faced by precommercial thinning and slash treatment equipment, machine failures are to be expected. Equipment should be relatively reliable and be capable of being quickly repaired when a failure does occur. Availability, reliability, and maintainability are equally important—whether a machine is Forest Service owned or is operated under contract. If the equipment is not reliable and maintainable, availability will be low, production will be low, and the cost of operation will be excessive.

One way to obtain good reliability, along with good availability and good maintainability, is to use and design (wherever possible) with mature, proven assemblies and components. Generally, over a period of time, assemblies and components will be upgraded and improved as failures occur and the causes of the failures become known and are eliminated. This is called reliability growth. For a slash treatment machine to meet Forest Service objectives it must have good reliability and also good maintainability. To accomplish this, use mature, proven assemblies and components in design and fabrication.

8. Maneuverability and Agility

Precommercial thinning and slash treatment equipment should have both good maneuverability and a high degree of agility. ***Maneuverability*** is the ability of a machine to make a series of changes in direction and position, while ***agility*** is the quickness and "grace" with which these changes in direction and position are made. Good arrangement and quick response of the machine's controls contribute to good maneuverability and agility.

Machines with horizontal-shaft reduction heads (having an inherently shorter coupling than single, vertical-shaft machines) usually display better maneuverability than vertical-shaft machines. Tracked vehicles, which—in general—have shorter turning radii than wheeled vehicles, usually have more maneuverability than wheeled vehicles. Reduced overhangs, lightweight, and a balanced machine contribute to good equipment agility.

Good examples of highly maneuverable machines, which also have good agility, are the John Deere 750B and 850B crawler tractors. These tractors have two hydrostatic transmissions, one for driving each track. This drive arrangement allows the tracks to be counter rotated, which enables the machines to turn quickly in their own lengths. A hydrostatic transmission also eliminates any "dead band" in the controls, which is often found in other types of transmissions. A precommercial thinning and slash treatment machine which meets Forest Service objectives must have both good maneuverability and a high degree of agility.

9. Safety

Implicit in all selection criteria is safety, especially when considering the reduction head main shaft. The equipment should be as safe to operate as is reasonably possible. All necessary safety equipment and devices (such as guards, shields, rollover protection, spark arrester, etc.) should be in place and not removed before or during operation. The maximum safe operating slope should be known and the machine should not be operated in areas having greater slopes.

MACHINE CONFIGURATION & CHARACTERISTICS

Each of the selection criteria has been discussed, and a selection made where the criteria allows a choice. Based on this, a slash treatment machine to meet Forest Service objectives would have the following configuration and characteristics:

1. Horizontal-shaft reduction head
2. Have fixed-tooth cutters
3. Use an integral, self-propelled carrier
4. Be a tracked machine
5. Have a single engine to drive the slash treatment tool and the prime mover through a hydrostatic transmission
6. Have a high, forward, full-view, enclosed, and air conditioned operator position
7. Have high reliability and good maintainability
8. Have high maneuverability and agility
9. Be as safe to operate as reasonably possible.

Two other items are: (1) the horizontal head should be balanced and free floating with down stop limits, and when lifted should raise vertically and not move out or forward and (2) for high reliability as many as possible and practicable mature and proven assemblies and components should be selected and used.

All this could lead to the selection and use of the Madge Rotoclear fixed-tooth horizontal shaft reduction head, carried by a modified John Deere 750B long-track dozer without the dozer blade. The reason for selecting the JD750B long-track as the slash treatment carrier is that it has a well-engineered and proven hydrostatic transmission. For this combination to work effectively, a necessary modification to the 750B would be to provide a higher power engine (in the range of 300 to 400 hp; presently 140 hp), and turn the operator position around so the operator would have a full view of the immediate area to be treated.

The higher power engine should be fitted with a triple (presently a double) or four-position hydraulic pump drive. The two lower pump drives of the triple, or four-position pump drive, would drive the JD hydrostatic transmission and the upper drive(s) would drive hydraulic pump(s) that would power the slash treatment tool. It would also be possible to retain the JD splitter drive and drive the hydraulic pump, which powers the slash treatment tool from the front of the higher powered engine. Figure 1 is an artist's concept of what such a Rotoclear/750B-based machine, which would meet Forest Service objectives in precommercial thinning and slash treatment, would look like.

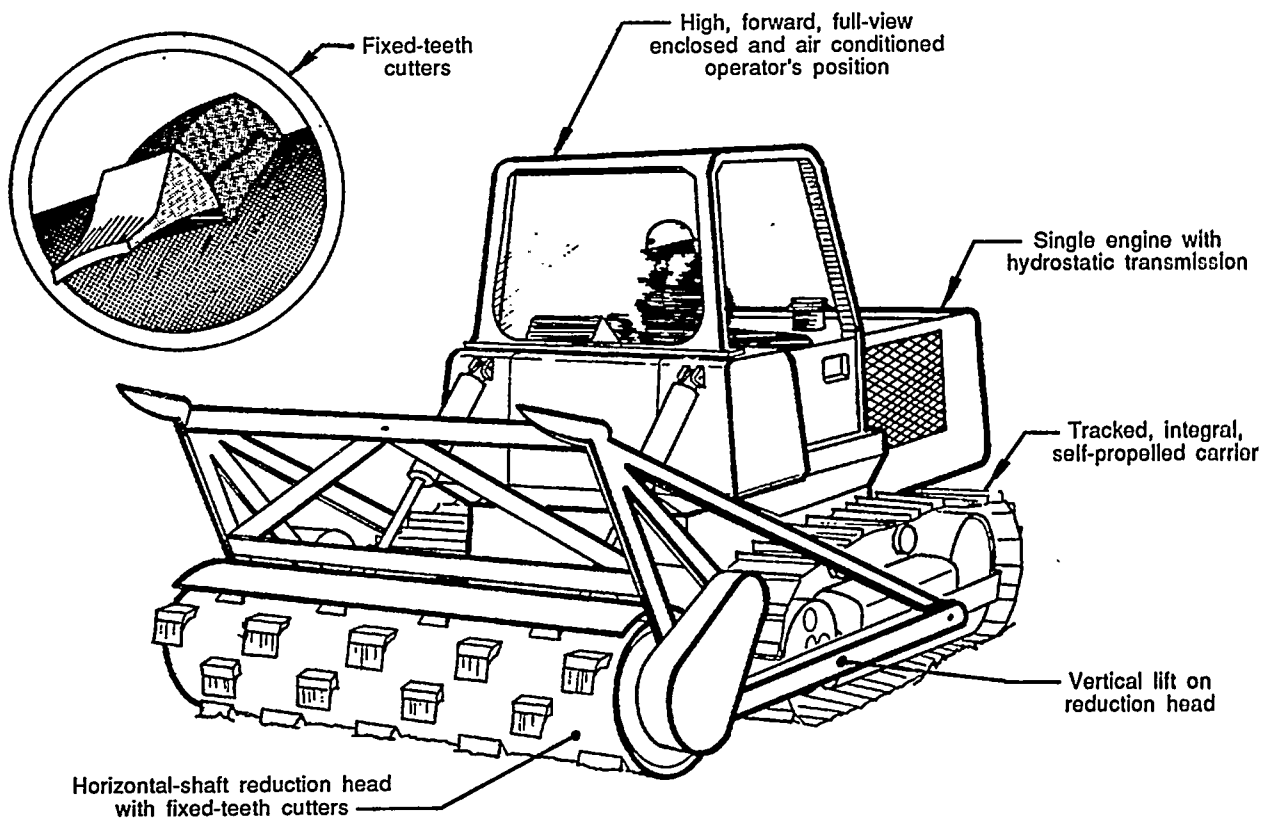

Figure 1. Artist's concept of a machine to meet Forest Service objectives in precommercial thinning and slash treatment.

The higher horsepower engine would provide power both to the slash treatment tool and carrier propulsion. Providing higher engine power and propelling the carrier with this much higher powered engine is possible because the hydrostatic transmission of the JD750B tractor limits the amount of power to that which it can safely transmit.

ESTIMATED OPERATING COSTS

Using analogy and industrial cost estimating techniques, estimated costs of a production machine such as seen in figure 1 would be between $200,000 and $250,000. Using parametric cost estimating techniques, the estimated hourly operation cost of the this machine would

be $200 to $250 per hour. Table 1 shows travel speeds, production rates, and costs per acre when using a field efficiency of 80 percent at machine operating costs of $200 and $250 per hour. Field efficiency is the ratio expressed in percent of the actual field area worked to the theoretical field area which would be worked if there were no turning, maneuvering, and other delays.

Table 1. Operating speed, production rate, and cost per acre

Travel speed (mph)	Production rate (acre per hour)	Cost per acre ($) at machine cost per hour $200	$250
0.5	0.36	556	694
1.0	0.73	274	342
1.5	1.09	183	229
2.0	1.45	138	172
3.0	2.18	92	114

It is estimated that this machine can operate at 1/2 to 2 mph; maybe up to 3 mph in light slash and good terrain. As seen in table 1, this would result in costs per acre of $92 to $694. A most likely operating speed would be around 1-1/2 mph, which would result in a cost per acre of $183 to $229.

DEMONSTRATION/VALIDATION MACHINE

Assembly and demonstration of a demonstration/validation model constructed from as many as possible mature and proven components would incur the least cost and be the fastest way to validate a horizontal-shaft, fixed-tooth, tracked slash treatment machine. In summary, the recommended features for a demonstration/ validation precommercial thinning and slash treatment machine are horizontal shaft, fixed-tooth cutters, hydraulically powered reduction head carried and powered by a single engine, tracked, hydrostatic transmission equipped prime mover (see the Summary Data Sheet).

Using this demonstration/validation machine, demonstrations and tests could be conducted to validate production rates and costs. The machine would also be expected to do useful work. Hopefully, the reliability and production rates would be attractive enough to allow carrying out large precommercial thinning and slash treatment projects. This in turn could attract a manufacturer to produce machines so they would be available to potential Forest Service contractors.

DEVELOPMENT TIME & FUNDING

To complete the demonstration/validation phase in the development of a precommercial thinning and slash treatment machine that will meet Forest Service objectives in the treatment of thinning and logging slash, a demonstration/ validation model must be fabricated. While it would be possible for SDTDC to design and assemble such a model to meet Forest Service objectives, more rapid development would be possible by contracting. A well-designed and -built demonstration/ validation model is estimated to cost $300,000 to $400,000; it should take 1 year to build. Preparation and administering the contract and field testing would require $125,000 to $175,000 over a 3-year period.

SUMMARY DATA SHEET
Advanced Design Precommercial Thinning and Slash Treatment Machine

EQUIPMENT

Designation:	Advance Design Precommercial Thinning and Slash Treatment Machine
Status:	Concept
Estimated Production Unit Cost:	$200,000 to $250,000

REDUCTION-HEAD MECHANISM

Type:	Horizontal shaft
Cutters:	Fixed tooth, 56, wedged into pockets welded to rotor
Width of cut (ft-in):	7-6
Maximum material size:	Unlimited
Working material size (in):	7
Type of drive:	Hydraulic
Rotational speed (rpm):	600 to 900

PRIME MOVER

Type:	Tracked
Diesel engine net power (hp):	300 to 400
Transmission:	Hydrostatic

MACHINE DATA

Width (ft-in):	8-8 to 9-0
Length (ft):	16 to 17
Height (ft):	10 to 11
Weight (lb):	30,0000 to 40,000
Ground pressure (psi):	6.2 to 7.2