



by John E. Baumgras

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## **BETTER LOAD-WEIGHT DISTRIBUTION IS NEEDED FOR TANDEM-AXLE LOGGING TRUCKS**

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# **BETTER LOAD-WEIGHT DISTRIBUTION IS NEEDED FOR TANDEM-AXLE LOGGING TRUCKS**

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## **ABSTRACT**

To determine the GVW and axle weights of tandem-axle logging trucks hauling into two West Virginia sawmills, 543 truckloads of hardwood sawlogs were weighed. The results showed that less than 2 percent of the truckloads exceeded the 48,000 pound GVW limit. While 58 percent of the truckloads exceeded the 32,000 pound tandem-axle weight limit, the front-axle weights never exceeded the 18,000-pound single-axle limit and seldom exceeded 10,000 pounds. Because the trucks sampled carried an average of 93 percent of the load weight on the rear axles, they could not haul maximum payloads without exceeding the tandem-axle weight limit on the rear axles.

The wheelbase dimension of the trucks and the location of the body on the truck determined the distribution of load weight. From these results, a truck design guide was developed in the form of an easy-to-use nomogram. The configuration of tandem-axle logging trucks needs to be changed, and loggers should select a truck design that will provide the correct distribution of load weight and have the capacity to handle the front- and rear-axle loads needed for maximum payloads.

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**BY** DISTRIBUTING THE PAYLOAD weight so that both front and rear axle weights are maximized, loggers could very often increase payloads. This would also reduce axle-weight overloads that can result in heavy fines being levied on truck operators.

An increase in payloads would increase trucking efficiency. Martin (1971) reported that a 25-percent increase in tandem-truck payloads would reduce the hauling cost by 21 percent. Moreover, maximizing logging-truck payloads would help loggers maintain a more efficient harvesting system because trucking frequently regulates the productivity of the entire logging operation.

In a study at our Forest Products Marketing Laboratory, we found that the payloads transported by tandem-axle logging trucks were located so far to the rear of the truck that it was impossible to attain proper axle loading or maximum payloads. The results from this study point out a real need for improving payload weight distribution so that payloads can be consistently maximized within the legal axle-weight limits prescribed by law.

## THE AXLE-WEIGHT STUDY

The study was made at two West Virginia sawmills. At one mill, 464 loads of logs were weighed, on 10 tandem-axle trucks hauling from several different sites. At the second mill, 79 loads were weighed, on 4 tandem-axle trucks hauling from 2 different sites. All the loads weighed were hardwood sawlogs. None of the trucks weighed were equipped with log loaders.

The 464 loads weighed at the first mill were unloaded with a forklift truck. We felt that this method of unloading might affect the truck loading and subsequent weight distribution because all logs had to be accessible to the forklift working between the stakes on the truckbed. Therefore the second sampling

site was selected at a mill where trucks were unloaded with trip stakes.

By weighing front and rear axles separately, both loaded and empty, we were able to determine payload weight on the front axle as well as on the rear tandem axles. Dividing the payload on the rear axles by the total payload, we were able to calculate the percentage of the payload transferred to the rear axles. This procedure provided a measure of weight distribution and served as the basis for estimating the load center of gravity (LCG). The following formula for calculating the load center of gravity, measured in inches from the front axle, was derived from a load-transfer equation presented by Fitch (1969):

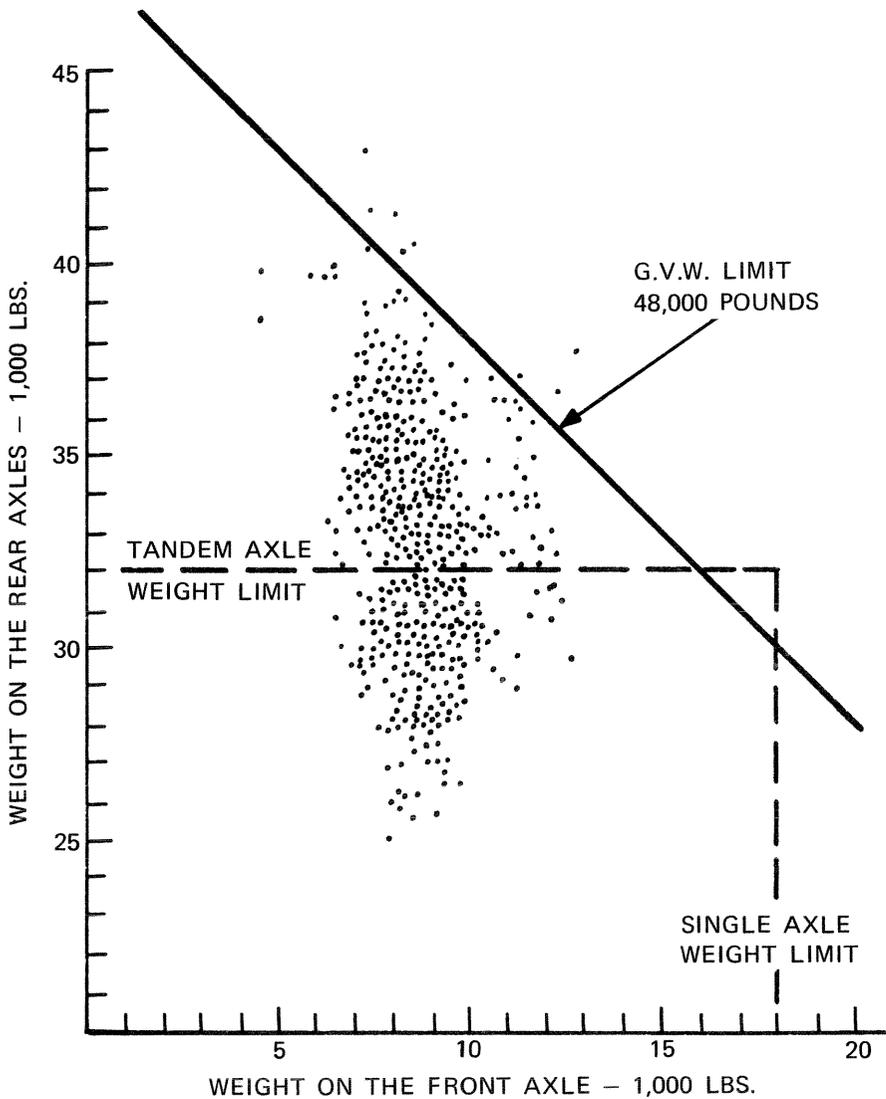
$$\frac{\text{Payload rear axle}}{\text{Total payload}} (\text{Wheelbase}) = \text{LCG (inches from front axle)}$$

## GROSS VEHICLE WEIGHTS AND AXLE WEIGHTS

The gross vehicle weight (GVW) limit in West Virginia is 48,000 pounds for three-axle trucks of the wheelbase dimensions we sampled (*W. Va. Dep. Motor Vehicles 1968*). Less than 2 percent of the truckloads sampled exceeded this GVW limit (table 1). Eleven of the 14 study trucks never exceeded 48,000 pounds GVW. The average GVW sampled was 41,465 pounds, and in most cases several thousand pounds of payload could have been added without exceeding the GVW limit.

Although the weight limit for single axles is 18,000 pounds (*North American Rockwell 1970*) none of the trucks used in the study were equipped with front axles or tires capable of safely handling the maximum legal single-axle load. Front-axle weights seldom exceeded 10,000 pounds (fig. 1). The average front-axle weight for all trucks was 8,675 pounds, and the front-axle weights of in-

Figure 1.—Scatter diagram of the front and rear axle weights sampled.



dividual trucks ranged from 7,538 pounds to 11,590 pounds (table 1).

The rear tandem axles of the trucks weighed were frequently overloaded; 58.1 percent of the truckloads exceeded the 32,000-pound tandem-axle weight limit (*North American Rockwell 1970*). All 14 sample trucks carried loads that exceeded the tandem-axle weight limit. However, the frequency of overloads varied from truck to truck, ranging from 9.1 percent to 94.4 per-

cent. The average weight of the rear axles for all truckloads was 32,790 pounds.

The average payload hauled by all trucks was 25,618 pounds. The average payloads for the individual trucks ranged from 22,296 pounds to 29,893 pounds. For all loads sampled, the average payload carried on the front axle was 1,932 pounds and the average payload carried on the rear axles was 23,686 pounds.

Table I.—Average truck, axle, and payload weights

Truck No.	Loads sampled	Combined weight — payload and truck					Payload weight		
		GVW	Loads over GVW limit <sup>a</sup>	Rear tandem axles	Loads over tandem axle limit <sup>b</sup>	Front axle <sup>c</sup>	Carried on front axle	Carried on rear axles	Total payload
	No.	Lbs.	Percent	Lbs.	Percent	Lbs.	Lbs.	Lbs.	Lbs.
1	22	38,977	0	30,763	31.8	8,213	1,333	21,768	23,102
2	20	41,295	0	32,640	50.0	8,655	1,950	23,565	25,515
3	20	39,766	0	31,808	40.0	7,958	1,363	22,208	23,571
4	17	41,476	0	33,222	64.7	8,254	1,854	24,162	26,016
5	36	43,643	0	34,778	94.4	8,855	2,055	26,048	28,104
6	55	38,441	0	29,643	9.1	8,798	1,548	20,748	22,296
7	18	44,161	0	33,273	77.8	10,887	4,977	24,783	29,761
8	20	45,853	15.0	34,263	75.0	11,590	4,490	25,403	29,893
9	66	40,898	0	31,377	36.4	9,520	2,425	21,877	24,303
10	73	40,126	0	30,874	38.4	9,251	1,751	22,084	23,836
11	31	40,603	0	32,816	55.8	7,787	1,867	24,196	26,063
12	39	42,445	5.1	34,907	76.9	7,538	698	25,087	25,785
13	50	42,864	0	34,701	92.0	8,162	1,972	26,031	28,004
14	76	42,748	3.9	35,120	86.8	7,627	1,467	25,490	26,958
All trucks	543	41,465	1.46	32,790	58.1	8,675	1,932	23,686	25,618

<sup>a</sup> GVW limit equals 48,000 pounds.

<sup>b</sup> Tandem-axle limit equals 32,000 pounds.

<sup>c</sup> No front-axle weights exceeded the single-axle weight limit.

## LOAD WEIGHT DISTRIBUTION

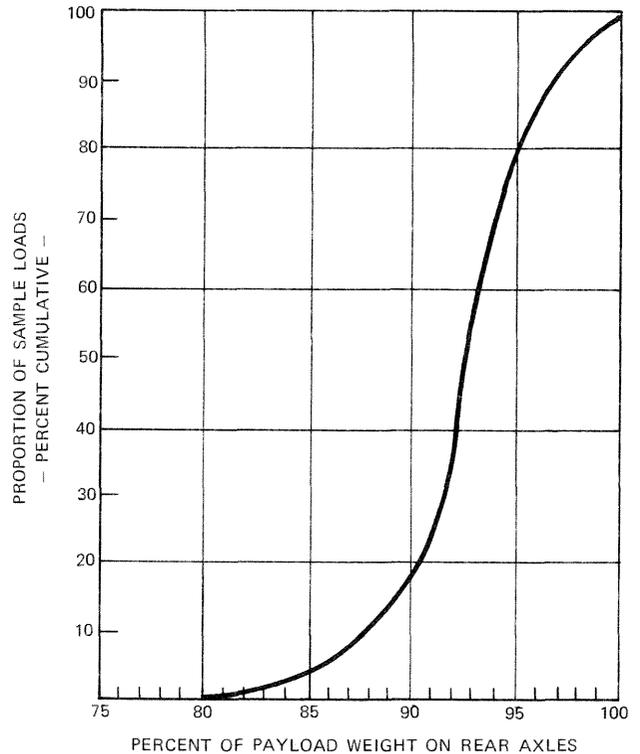
Although the truck payloads we sampled were not excessive, the rear axles were frequently overloaded because so much load weight was carried on the rear axles. Half of the truckloads sampled carried more than 93 percent of the load weight on the rear axles (fig. 2).

The distribution of load weight is determined by the location of the load center of gravity (LCG) relative to the truck axles. When the load center of gravity is measured from the front axle, the proportion of load weight on the rear axles is equal to  $LCG \div Wheelbase$ .

The distance from the front axle to the load center of gravity is controlled by the location of the truck body on the truck chassis and the position of the load of logs on the truck body.

We measured the location of the truck body from the front axle to the headboard. The headboard was used as a reference point because it regulates the forwardmost place-

Figure 2.—Proportion of payload weight carried on the rear axles.



ment of logs and therefore regulates the distribution of load weight.

We determined the location of the load center of gravity on the truck body by first estimating the load center of gravity relative to the front axle and then subtracting the distance from front axle to headboard. The difference represents the distance from the body headboard to the load center of gravity.

The truck wheelbase was measured from the front axle to the midpoint of the rear tandem axles.

The individual trucks were loaded very consistently. Hence the location of the LCG and the resulting proportion of load weight on the rear axles showed little variation between loads (table 2).

The between-truck weight - distribution variations were due primarily to the dimensions of the trucks rather than the placement of the load on the truck. We computed a regression equation to predict the mean LCG for each truck:

$$Y = 102.39 + 0.96X_1 \quad [1]$$

In which:

Y = mean LCG

$X_1$  = distance from the front axle to the headboard.

The coefficient of determination was 0.75, which means that 75 percent of the variation in the mean LCG was accounted for by regressing on the truck-body location.

Using both wheelbase length and body location, we computed a regression equation for predicting the average percentage of payload on the rear axles of each truck:

$$Y = 139.3 + .44X_1 - .42X_2 \quad [2]$$

In which:

Y = mean percent payload weight on the rear axles

$X_1$  = distance from front axle to headboard of truck body

$X_2$  = length of truck wheelbase.

The coefficient of determination ( $R^2$ ) for equation 2 was 0.78 and the standard error of the estimate was 1.9 percent.

The four trucks unloading with trip stakes had less variation in load center of gravity than those unloaded with a lift truck (table 2). The average percent payload on the rear axles was about the same for both groups of trucks.

Table 2.—Truck dimensions and load weight distribution statistics

Truck No. <sup>a</sup>	Loads sampled	Wheel-base <sup>b</sup>	Body location <sup>c</sup>	Percent of payload on rear axles		LCG inches from front axle	LCG inches from headboard of body	
				Mean	Standard deviation	Mean	Mean	Standard deviation
	No.	Inches	Inches					
1	22	184	72	94.2	1.74	173.3	101.3	3.22
2	20	186	70	92.4	1.53	171.8	101.8	2.85
3	20	186	75	94.2	2.22	175.3	100.3	4.12
4	17	186	72	92.8	1.46	172.7	100.7	2.72
5	36	198	86	92.7	1.62	183.5	97.5	3.25
6	55	185	79	93.1	2.02	172.2	93.2	3.72
7	18	212	78	83.3	2.30	176.5	98.5	4.88
8	20	211	81	84.9	2.63	179.1	98.1	5.56
9	66	188	76	90.0	2.46	169.2	93.2	4.60
10	73	185	70	92.7	2.17	171.5	101.5	3.99
11	31	196	80	92.8	2.65	182.0	102.0	5.20
12	39	188	80	97.3	2.13	183.0	103.0	4.03
13	50	196	86	92.9	2.54	182.1	96.1	4.99
14	76	206	90	94.6	2.14	194.8	104.8	4.35

<sup>a</sup> Trucks 1 through 4 were unloaded with trip stakes, trucks 5 through 14 were unloaded with a forklift truck.

<sup>b</sup> Measured from front axle to midpoint of tandem rear axle.

<sup>c</sup> Measured from the front axle to headboard of truck body.

## MAXIMIZING PAYLOADS WITHOUT AXLE OVERLOAD

The trucks we sampled should have carried proportionately more load weight on the front axle. If the distribution of load weight is not changed, axle overloading can be avoided only by reducing payloads. However, near-maximum payloads can be hauled without axle overloading if the load weight is properly distributed.

The location of the load center of gravity dictates load-weight distribution, which in turn dictates the maximum payload that can be transported without exceeding specified axle-weight limits or the rated capacity of the axles. The relationship between the location of the load center of gravity and the maximum payload is shown in figure 3. This represents a 200-inch wheelbase, tandem-axle truck with empty front and rear axle weights of 7,000 and 9,000 pounds respectively. Assuming the desired loaded axle weights are 16,000 pounds on the front and 32,000

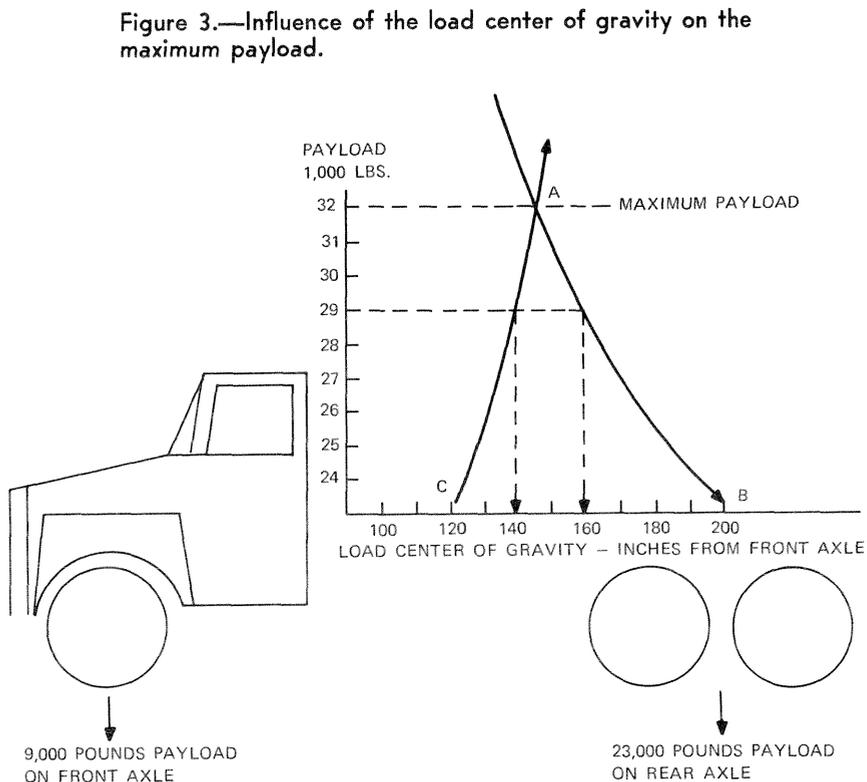
pounds on the rear, 9,000 pounds of payload weight can be carried on the front axle and 23,000 pounds on the rear.

Curve AB in figure 3 represents the combinations of payload weight and LCG that will result in rear-axle weights of 32,000 pounds, or 23,000 pounds of load weight on the rear axles. Any load weight and LCG combination that intersects to the right of AB will overload the rear axles. This curve is described by the equation:

$$\text{Maximum payload} = \frac{\text{Max. load on the rear axles}}{\text{LCG} \div \text{wheelbase}}$$

Curve AC (fig. 3) represents the combinations of payload weight and LCG that result in front-axle weights of 16,000 pounds, or 9,000 pounds of load weight on the front axle. Any load weight and LCG combination that intersects to the left of AC will overload the front axle. This curve is described by the equation:

$$\text{Maximum payload} = \frac{\text{Max. load on front axle}}{1 - (\text{LCG} \div \text{wheelbase})}$$



The AB and AC curves intersect at the maximum payload and the optimum load center of gravity. The maximum payload is equal to the sum of the maximum axle loads. The optimum LCG is at the point where the proportion of load weight carried by each axle is equal to the ratio of the maximum axle load and maximum payload.

In this case, the optimum LCG is 143.75 inches. The proportion of load weight on the rear axle is equal to  $143.75 \div 200$  or .72 which is equal to  $23,000 \div 32,000$  pounds. The proportion of load weight on the front axle would equal  $1 - (143.75 \div 200)$  or .28, which is equal to  $9,000 \div 32,000$  pounds.

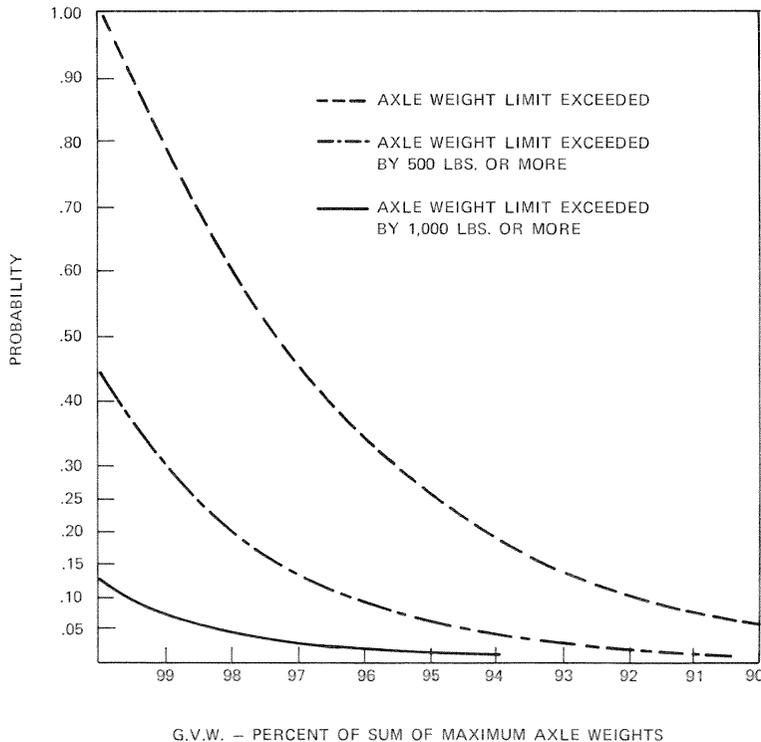
For the 543 loads sampled, the average payload on the rear axle was 93 percent. For this example, this would correspond to a 186-inch center of gravity:  $.93 \times 200 = 186$ . With the LCG at this point, any load in excess of 25,000 pounds will result in overloaded rear axles. This is 7,000 pounds less than the maximum legal payload.

Because loggers cannot precisely position the center of gravity of each load of logs, the LCG varies from load to load. Although this variation seems to be limited, when GVW is equal to the sum of the maximum axle weights, this variation can cause axle-weight overloads even when the mean LCG is located at the optimum point.

To prevent this type of overloading, the GVW of logging trucks should be less than the sum of the maximum axle weights. This margin allows the LCG to vary without overloading the axles. In the preceding example, the sum of the maximum axle weights is 48,000 pounds. If the payload is reduced to 29,000 pounds so that the GVW is 45,000 pounds, the LCG can vary approximately 20 inches without axle overload (fig. 3).

The nature of the relationship between payload reductions and the probabilities of axle overload is shown in figure 4. In this example, we assumed that the mean LCG was located at the optimum position for the

Figure 4.—The relationship between GVW and the probability of overloads.



maximum payload, and that the standard deviation was 4.0 inches, which is about the average value for the standard deviation of LCG shown in table 2.

Assuming that the LCGs are normally distributed, we can compute the probabilities of overload that are given in figure 4. By reducing the payload 5 percent so that the GVW equals 95 percent of the sum of the maximum axle weights, the probability of overload is only .26 and the probability of a 500-pound overload is less than .06.

## RECOMMENDATIONS

The study results show that tandem-axle logging trucks can transport near-maximum payloads without significant axle overload, if more payload weight is shifted to the front axle. To make this change, loggers can change the configuration of the log loads or change the configuration of the logging trucks.

The load configuration can be changed by loading all logs as far forward on the truck body as possible. This practice would shift the weight of 8-, 10-, 12-, and 14-foot logs forward and transfer more weight onto the front axle.

The trucks in this study were loaded so most of the short logs were centered on the truckbed rather than butted up against the headboard. This was done because the retaining stakes were located too far back on the truckbed. By moving the stakes on the truckbed or adding stakes and load binders, the shorter logs could be secured in a forward-most position.

To optimize the distribution of load weight, the configuration of logging trucks must be changed. With the trucks and sawlog lengths observed in this study, it would be impossible to move the load forward far enough to load the front axle properly. Furthermore, the analysis of weight distribution showed that the dimensions of the logging truck are the most important determinants of weight distribution.

We have prepared a guide to selecting the correct combinations of wheelbase length and

body location (fig. 5). This guide is designed to help loggers obtain the distribution of load weight that is compatible with the relative capacities or legal limits for the front and rear axles. The relationship between weight distribution and truck configuration is based upon equation 1.

To use the nomogram, both the maximum payload and maximum load on the rear axles must be determined. The payload weight is the difference between the maximum GVW and the weight of the empty truck. The load on the rear axle is the difference between the maximum tandem-axle weight and the rear-axle weight of the empty truck.

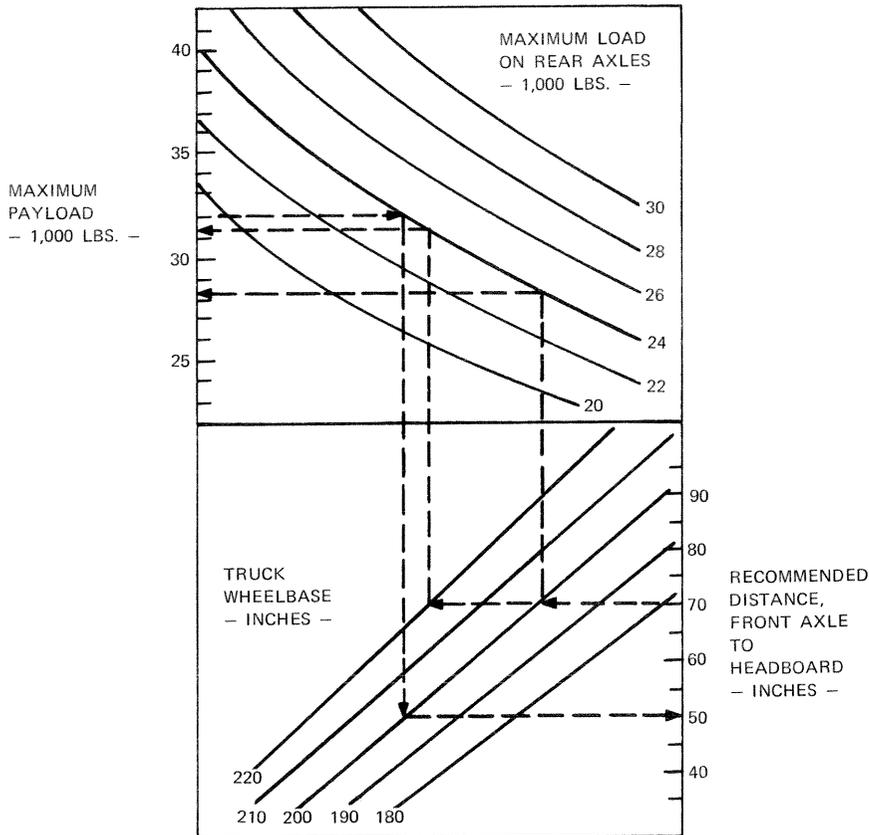
The maximum GVW and rear-axle weights used in these calculations should not exceed either the legal weight limits or the rated capacity specified by the manufacturer. Furthermore, the GVW should not exceed the sum of the front and rear axles weight capacities.

For example, if the front axle and front tires are rated for 12,000 pounds, and the rear axles are rated for 32,000 pounds, regardless of the legal GVW limit, the GVW of the truck shouldn't exceed 44,000 pounds.

To demonstrate the use of the nomogram, suppose that the maximum GVW equals 48,000 pounds and the rear-axle weight limit is 32,000 pounds. If the tare weight of the truck is 16,000 pounds, the maximum payload would equal 32,000 pounds. If the chassis and body weight on the rear axle of the unloaded truck is 8,000 pounds, the maximum load on the rear axles would equal 24,000 pounds. In this case, a 200-inch wheelbase truck should have the headboard located no more than 50 inches from the front axle (fig. 5).

Using figure 5 in reverse, suppose 70 inches is the minimum front-axle-to-headboard distance that could be attained on a particular truck. To maintain a load on the rear axles of 24,000 pounds or less, a truck with a 200-inch wheelbase shouldn't carry a payload exceeding approximately 28,000 pounds. Increasing the wheelbase to 220 inches would increase the allowable payload to approximately 31,000 pounds (fig. 5).

Figure 5.—Tandem-axle logging truck design guide.



## DISCUSSION AND SUMMARY

Loggers should put more load weight on the front axle of the tandem-axle logging truck if they expect to maximize payload without exceeding the legal axle-weight limits. To do this, they should select a truck design that will properly distribute the weight between the front and rear axles and safely handle the added front-axle loads.

From the truck-design guide, the combinations of truck wheelbase length and body location can be determined that will distribute the load weight in accordance with the relative capacities of the front and rear axles. The truck dimensions recommended by this guide may require loggers to select a longer-wheelbase truck or one with a setback front-axle design. The bunks and log-retaining stakes on the truck body should also be located as far forward on the truck as possible.

The legal axle-weight limits or the weight capacity of the truck axles should determine how much weight should be carried by both front and rear axles. Certainly, every logger should not load the front axle to the maximum single-axle weight limit, which varies from 18,000 pounds to 22,400 pounds for the various eastern states (4). Such loads on the steering axle would create severe handling problems. However, the average front-axle weight sampled was 8,675 pounds, and any improvement over this would help reduce rear-axle overloads and increase legal payloads.

To keep the capacity of the front axle in line with increased front-axle loads, trucks should be equipped with heavy-duty front axles and tires. Front axles with ratings of 16,000 to 18,000 pounds are offered as options by many truck manufacturers. Wider tires will keep the added loads within the legal weight-per-tire-inch restrictions.

The added cost of these heavy-duty components should be compared with the expected benefits, such as increased payloads and safer operation that would be realized over the life of the truck.

Loggers trying to maintain the most efficient and productive operations possible should carefully select logging trucks, truck components, and truck bodies. To maximize payloads and minimize costs, every aspect of truck design should be considered.

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