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Project Report
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7100–Engineering Operations

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National Central Tire Inflation Program— Olympic National Forest Field Operational Tests

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National Central Tire Inflation Program—Olympic National Forest Field Operational Tests

by

Deborah J. Taylor
Civil Engineer

Forest Service—USDA
Technology & Development Center
San Dimas, CA 91773

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Acknowledgments

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Executive Summary

The Forest Service is conducting a two-part test program to evaluate the economic impact of lowered tire pressures on road construction and maintenance and on timber hauling. A field operational test conducted during the Moores Creek timber sale on the Boise National Forest was the first use of lowered tire pressures on an actual timber operation. The Olympic National Forest demonstration is the second field operation test to be held in the Western United States.

From January 7 to March 25, 1987, six 10-yard, three-axle dump trucks hauled rock from a rock pit over 10 miles of aggregate-surfaced roads. During the road-surface replacement, 90 percent of the haul was operated with the steering, driving, and trailer axle tire pressures determined appropriate for the speeds, loads, and weather conditions of the haul area—that is, between 25 and 54 pounds per square inch (psi). One truck was equipped with an onboard central tire inflation (CTI) system. The five trucks not equipped with a CTI system had tire pressures adjusted manually through an airing station at the rock pit when the trucks were loaded with rock. For the remaining 10 percent of the haul, the trucks operated at their normal tire pressures of 90 psi.

Limited quantitative measurements were made throughout the course of the demonstration. The following test results (based largely on opinions and observations regarding the effects of lowered tire pressures on the interrelationship among the road, the vehicle, and the driver) indicate that CTI technology can be beneficial in road maintenance operations:

- No road maintenance was required in 3 weeks of haul with lowered tire pressures; normally, this haul route requires maintenance every 3 days during a rock haul.
- Lowered tire pressures increased crest-to-crest distances between washboards and decreased the impact on both drivers and vehicles.
- After only 3 days of haul with high tire pressures, the Forest requested returning to lowered tire pressures because of extensive road damage (that is, potholes).
- No tire damage occurred during this haul. There normally are five to seven flats per week. (Part of this improvement is attributed to the use of radial rather than bias ply tires and part to the use of lowered tire pressures.)
- The drivers felt that lowered tire pressures improved vehicle stability when dumping and spreading.
- The drivers liked the smoother ride and overall handling of lowered tire pressures.

Introduction

Road Technology

Currently, the Forest Service maintains over 340,000 miles of roads to transport forest products from National Forests. Approximately 95 percent of these roads are unpaved. The cost of transporting forest products includes not only the actual cost of transportation, but it also includes the cost of constructing and maintaining the roads. When faced with budget cuts, "doing the most with what you have" is important. Efforts to save dollars require an investigation of methods to reduce costs in all phases of existing road technology. Much of the direction for the current effort of the Forest Service is set by the Road Technology Improvement Program (RTIP).

Truck Tires, the Road, and the Vehicle

As recommended in RTIP, the San Dimas Technology & Development Center (SDTDC) is investigating the effects of tire pressure on the cost of transporting forest products over Forest Service roads. An initial report on this effort was published in *Engineering Field Notes*, Volume 15, January–March 1983, in an article on systems for decreasing vehicular damage to forest roads. SDTDC engineers are studying the effect of lowered pressures on haul truck tires and the basic interrelationship among the tires, the road, and the vehicle. Both the U.S. Army and SDTDC have already found that lowering tire pressures on low-speed, unpaved roads may result in the following benefits:

- Reduced road maintenance requirements
- Reduced road surfacing requirements
- Reduced driver fatigue and injury
- Reduced vehicle operating costs (for example, tire replacement, fuel, truck maintenance)
- Increased vehicle mobility

Lowered Tire Pressures

Appropriate tire pressure is dictated by vehicle speed, tire construction, loading, and road surface strength. Central tire inflation (CTI) systems enable a vehicle driver to adjust tire pressure to an appropriate level from inside the vehicle cab. Although preliminary work convinced the Army to equip its 5-ton trucks with CTI systems for mobility purposes, there was no evidence of other benefits.

The Forest Service is conducting a two-part test program to quantify the relationship between tire pressure and road and haul costs, as well as to familiarize the logging industry with the lowered tire pressure concept. Part one consists of structured tests to quantify the interrelationship among the tires, the road, and the vehicle, along with the associated benefits of appropriate tire pressures. Part two consists of a series of field tests that should (1) demonstrate to the logging industry the concept of lowering tire pressures on unpaved roads and (2) qualitatively evaluate the effectiveness of CTI systems under actual field conditions.

Objectives

The rock haul in the Olympic National Forest near Quinault, Washington, was the first field test to use lowered tire pressure on a road surface replacement job. This field activity was selected to demonstrate the concept and associated benefits of hauling rock with lowered tire pressures and to determine the effects on the following:

- Road surfacing
- Road maintenance (washboard, dust, surface replacement)
- Haul cost (fuel, roundtrip time, tire cost, truck maintenance)
- Driver fatigue and injury

Project Location And Description

The entire 10-mile haul route (figure 1) was over aggregate-surfaced roads—Roads 2220 and 2310—and Road 2280, which has spot surfacing. This haul route was chosen specifically to test the effect of reduced tire pressure on sections of the route known to have a high surface moisture content and little surface strength.

During the test program, from January 7 to March 25, 1987, six 10-yard dump trucks were operated with lowered tire pressures while hauling rock from a rock pit just off Road 2310. Approximately 90 percent of the haul was to be operated at a tire pressure determined to be safe for the speeds, loads, and weather

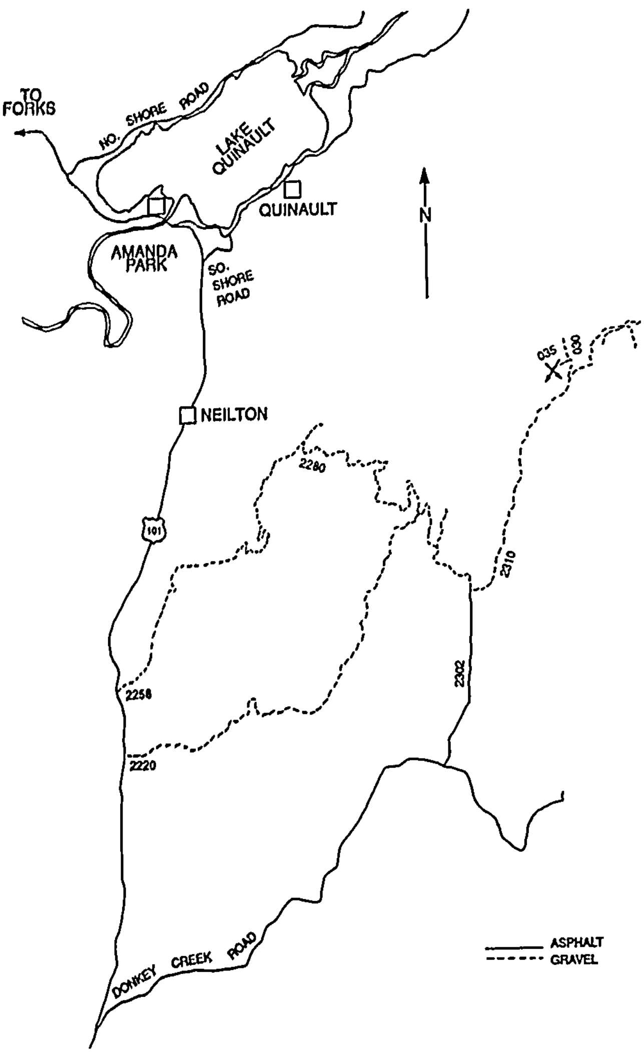


Figure 1. Layout of field operational test haul route.

conditions encountered. During the duration of the test program, about 35 inches of rainfall was measured, which is below the normal level for this time of year. In addition, a lot of freeze-thaw was observed. Appendix A presents the original test plan, with details on the terms and conditions for conducting the field operational tests.

Test Procedures

Conduct of the Test

During the first week of January 1987, five of the six 10-yard dump trucks that were designated to participate in this test were equipped with new radial 11R24.5 tires. The sixth truck was equipped with the same radial tires in early November 1986; at the same time, a CTI system was installed to check that it functioned properly and to familiarize the driver with its operation before testing began. The tires were to be kept in their original positions, as mounted at the beginning of the test program.

For the five trucks not equipped with a CTI system, the radial tire pressures were adjusted manually using an airing station at the rock pit (figures 2 and 3) when a truck was loaded with rock. The driving axle tires were set at 40 psi for the loaded condition. Steering axle tires were set at 55 psi for the entire haul.

When the trucks had completed dumping and spreading the load, the drivers used automatic deflation valves that plugged onto the tire valve stems (figure 4) to deflate the driving axle tires to 25 psi. Various pressures were used to keep tire footprint length and deflection (change of tire section height) constant for the different axle loads during the lowered pressure phase. Table 1 illustrates that, from tire footprints taken on the field, a 63 percent increase for the unloaded truck and a 69 percent increase for the loaded truck were obtained by decreasing tire pressures from 100 to 25 psi. The truck equipped with a CTI system operated with the same tire pressures as the other five trucks, but the driver could adjust pressures "on the roll" from within the vehicle cab.

All six trucks were parked overnight in Quinault, Washington. Before they left for Quinault, all trucks were aired up to 90 psi—one truck through the CTI system and the other five through an airing station at the junction of Roads 101 and 2220.

Data Collection

Limited field measurements were taken during the test program because this was a demonstration with primarily subjective evaluations. Drivers were responsible for keeping a daily record of fuel consumption, roundtrip times, total loads hauled, and total mileage. Records were kept of any tire or rim damage, including conditions causing the damage, the type of damage, tire mileage, tire pressure, and tire position on the vehicle. For test purposes, the trucks were limited to a maximum speed of 35 mph, which was considered appropriate for the loads, tire pressures, and road conditions.

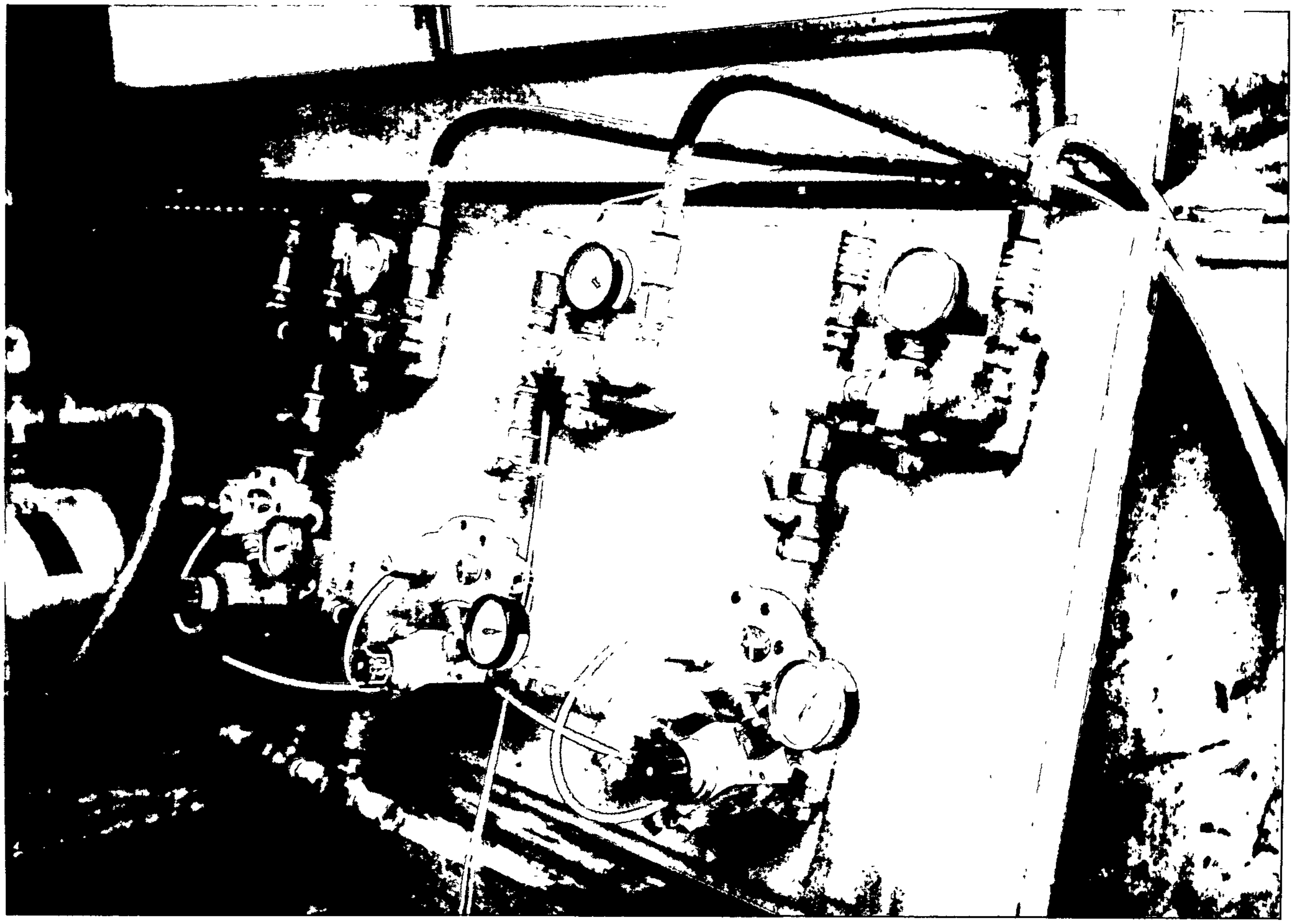


Figure 2. Airing station control panel.

During the test program, vehicles hauled exclusively over unpaved roads. Five test segments were selected along Road 2310 to test the effects of lowered tire pressures on a variety of road conditions—curves, grades, and moisture changes (figure 5). Table 2 characterizes the soil properties of each test segment (with detailed soil data included in appendix B). Nuclear moisture/density readings (to be verified with an oven-dry sample) were recorded, and documentation photographs were taken for each test segment.

As soon as drivers or test personnel observed washboard corrugation or pothole development, photographs were taken to document the progression. Daily weather information (for example, temperature, precipitation, and humidity) was obtained from a weather station in the vicinity.

Test Results

This test program was conducted to test the applicability of lowered tire pressure on nontimber-related hauls under extremely wet road surface conditions. The field test is just one of several projects to be conducted throughout the United States so as to involve a wide variety of applications and Regional conditions. Comments and observations made during the test program depend on the conditions particular to this type of haul application.

Tire Pressures

According to the original test plan, 90 percent of the total passes over the test road were to be run using lowered tire pressure, with the remaining

Figure 3. Inflating tires at airing station.

10 percent at high tire pressure (90 psi). The lowered tire pressures used are listed in table 3 for the axle loads indicated.

During the test program, a total of 1,069 loads of rock was hauled a total of 18,542 miles with lowered tire pressures, with the remaining 121 loads hauled 2,926 miles using high tire pressures. Sudden, unexpected changes in road and weather conditions did not develop during this test program. The original procedure outlined in the test plan was followed with few, if any, modifications.

Mileage

Based on an average roundtrip haul of 20 miles between the pit and spread site, the average distance each truck hauled over the test route was approximately 3,600 miles. The average distance each truck hauled was 3,100 miles at lowered pressure and 500 miles at high pressure. The trucks averaged 5,900 miles during the test program. Table 4 summarizes the actual loads and miles hauled by each of the six trucks for both the lowered and high tire pressure runs from January 1 through March 26, 1987.

Haul Costs

Truck Maintenance. Truck maintenance and repair costs comprise a significant portion of the overall haul costs. During the test program, three minor truck repairs were recorded—repair of a windshield wiper motor arm, replacement of a slashed tire hose, and welding of a fender. One driver recorded a broken canister. One truck reported a broken drive

Figure 4. Installation of automatic deflation valves.

line, air line, and walking beam bar, which showed evidence of cracking prior to testing. No additional changes in the conditions of the vehicles prior to hauling were observed. (Refer to appendix C for truck condition surveys.) All drivers agreed that, over an extended period of time, both the frequency and degree of truck maintenance and repair would either decrease or remain unchanged from using lowered tire pressure.

Fuel Consumption. The effect of lowered tire pressure on overall fuel consumption cannot be accurately defined for this test program. Daily fuel consumption records reflect the total mileage for the daily haul—the on-highway normal tire pressure mileage and the off-highway lowered tire pressure mileage. In addition, only 3 days, or 10 percent, of the entire haul period was run using normal tire pressure, as opposed to 90 percent at lowered tire pressure; this does not allow for a fair comparison of fuel consumption.

For this particular haul, the drivers did not notice any significant differences in fuel use between runs using lowered and normal tire pressures. Table 5 illustrates a comparison between the average fuel consumption for the haul during field testing and that for the prior year. Taking into account differences in weather and road conditions, drivers, and vehicle conditions between the 2 years of haul, there were no significant differences in fuel consumption.

Tire Damage. One of the largest haul cost factors is tire replacement. Bruises, breaks, and cuts are the dominant causes of tire failure on dump trucks. With a longer tire footprint (increasing the length of tire tread that is in contact with the road surface), the lowered pressure tires ran over large, sharp rocks in the pit area and on the low-speed, aggregate-surfaced roads without any tire damage. Also, the increased deflection in the tire sidewalls eliminated the tendency for rocks to get caught between the duals and cause blowouts.

During the test, tire damage did not occur. No flats were reported during the 11 weeks of haul using lowered and normal tire pressures. Normally, for this type of haul, approximately five to seven flat tires are reported a week. This is perhaps because of, in part, the change from bias ply to radial tires. However, based on the results of other tests as well as this one, much of the reduced tire damage can be attributed to lowered tire pressures.

Truck Handling and Driver Comfort

Because of the longer tire footprint generated by lowering tire pressure, drivers noticed less rattling and bouncing. They agreed that lowered tire pressure resulted in less discomfort to their backs and provided a more enjoyable ride. In most cases, they felt that steering was less responsive and the overall turning radius increased with lowered tire pressure, but only one trip was required to become familiar with the handling differences.

Of particular interest was the effect of lowered tire pressure on spreading the load. Because of the additional ground contact area, it was anticipated that the lowered pressure would decrease overall truck stability while spreading. According to the majority of drivers, lowered tire pressure did in fact increase overall truck stability while spreading. The lowered tire pressure actually "rolled-out" the previous spread,

Table 1. Comparison of contact areas for third-axle dual tires

Tire Pressure (psi)	*Footprint Dimensions[a]* *Length (in)*	*Width (in)*	*Contact Area[b] (sq in)*	*Total Load Per Tire (lb)*	*Average Static Ground Contact Pressure (psi)*
Loaded Truck					
100	9.2	7.5	38.0	4,600	121.1
40	13.9	8.1	61.9	4,600	74.3
Unloaded Truck					
100	5.7	6.7	21.0	1,700	81.0
25	8.7	7.4	35.4	1,700	48.0

[a]All dimensions represent the average of values measured for the four tires on this axle.
[b]Assumes 55 percent of total footprint area is actually in contact with the ground (due to tread pattern).

making a more solid surface for the next truck to spread.

There was some concern as to the effect of lowered tire pressure on the handling and stability of the steering axle. Several drivers felt that lowered pressure increased the tendency for the steering to wander or to track low spots in the road surface. In particular, poor drainage on Road 2310 resulted in the formation of water rivulets in both traffic lanes (figure 6), which developed into shallow grooves with continued haul traffic and rain. These grooves are characteristic of this haul road and were not caused by lowered tire pressure. The drivers did feel, however, that the lowered pressure increased the tendency for the vehicles to "pull into" or track the grooves. This is consistent with radial tire mechanics, but is overcome as drivers become familiar with the handling characteristics of trucks with radial tires at lowered pressures.

Road Maintenance

It was apparent to both the drivers and test personnel that, compared to prior hauls over this same haul route, the use of lowered tire pressures resulted in noticeable improvements in road surface conditions and decreased overall road maintenance requirements. According to the road crew, two forms of road surface damage are common to this haul route—washboarding and potholing. Both were significantly reduced by using lowered tire pressure.

Washboarding. Washboarding was essentially eliminated by the lowered tire pressure. Only on Road 2302 (which was on the haul route, but not within a test segment), over which the haul traffic was mixed with logging traffic, did the drivers experience any "chattering" when,using lowered pressures. During the high pressure phase, however, washboarding developed and progressed on several road segments, particularly on the adverse grades and curves. After returning to lowered tire pressures and running for a few days, truck chattering decreased and washboarding seemed to disappear.

Shortly after returning to lowered tire pressures, several drivers felt a slight but regular hesitation with the vehicles, particularly noticeable on the adverse grades and curves. A careful examination of the road and vehicles in these areas revealed that a regular corrugation still existed in the road surface. It seems that lowered tire pressure had not eliminated the washboarding but, rather, had stretched or lengthened the crest-to-crest distance and reduced ride harshness. Further testing would be required to determine whether washboarding would eventually disappear altogether.

Potholing. During prior hauls, pothole development had been a problem on Road 2310. Bill Elder, road crew foreman, stated that, on previous hauls over the same road, pothole development began as early as 3 days after the onset of haul. Spot blading was required at least three times per week, along with complete blading when necessary.

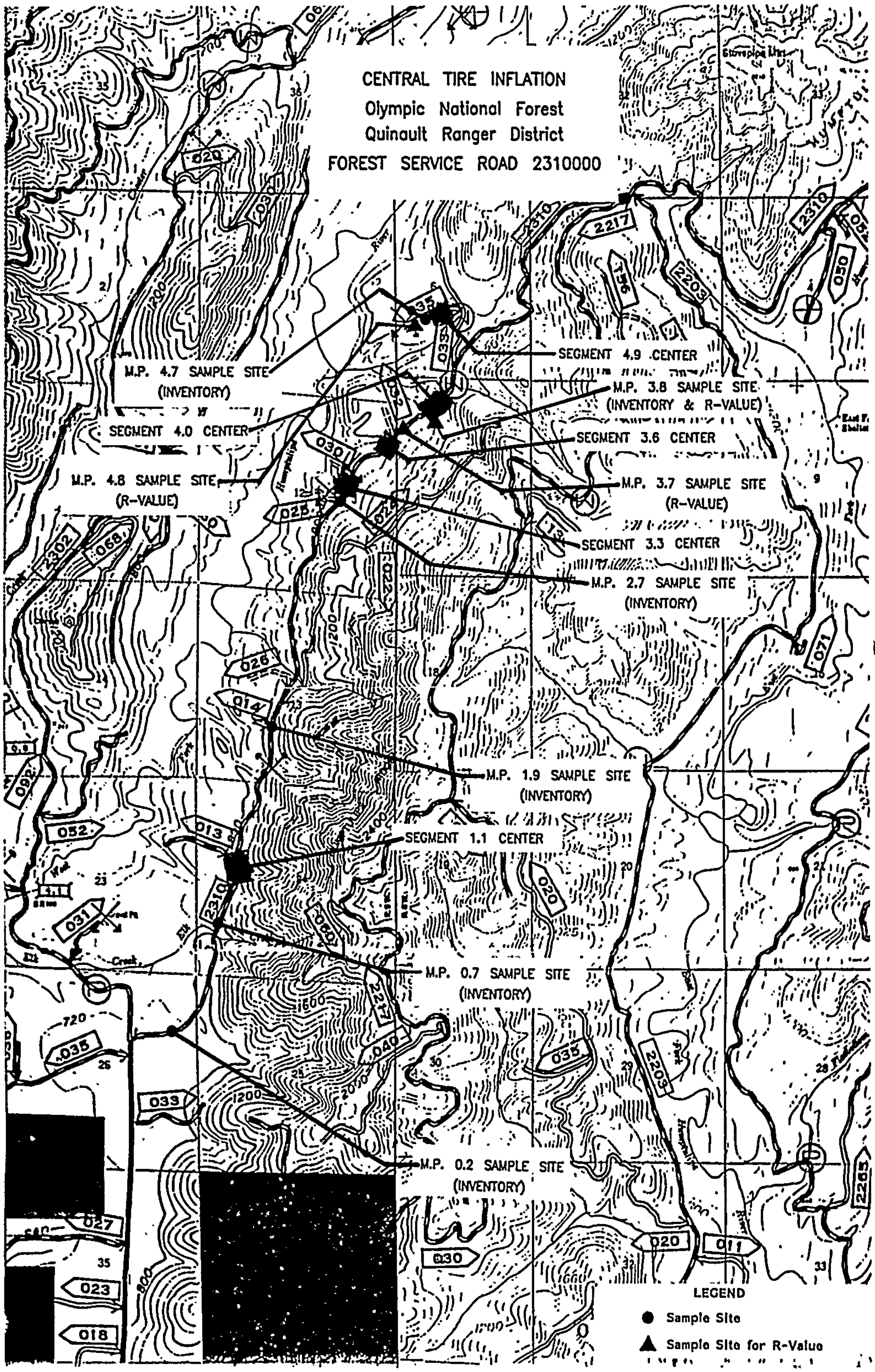


Figure 5. Test segments and designated soil sampling locations (for soil test analysis in table 2).

Table 2. Test segment description

Item	*Test Segment* 1	2	3	4	5	6
Description	'S' Curve	Favorable grade 100° curve	Slump segment; wet	Adverse grade straight	Ramp into pit	Adverse grade
Location (from #2310/#2220)	MP1.11 (#2310)	MP3.06 (#2310)	MP3.55 (#2310)	MP3.77 (#2310)	MP4.54 (#2310)	MP2.1 (#2220)
Road Layer[a] Depths:						
Layer 1 (surf)	0-2"	0-12"	0-8"	0-6"	0-10"	0-7"
Layer 2	2-6"	12" +	8-27"	6-16"	10" +	7-12"
Layer 3	6" +		27" +	16" +		12"+
Classification: Unified (1,2,3)	SP-SM,GW,GP-GM	SW,SM,GP-GM	SP-SM,GW,SM	SP/GW,GP-GM,GW-GM	SP-SM/GP-GM,GP-GM	GP-GM,GP-GM,SP-SM
Atterberg Limits Liq. Lim. (Layer 1,2,3)	NP	NP,40	25,49,NP	NP/26,40,78	NP/28,43	NP,NP,NP
Specific Gravity	2.93,2.65 (1&2)	2.9,NA (1&2)	2.88,2.75 (1&2)	2.78/2.87,2.67,NA (1,2,&3)	2.9,NA (1&2)	?; 2.79,2.63 (1,2,&3)
R-Value	To Be Provided					
Resilient Mod. CBR (95-90%)				21.7,19.7	25.6,17.4	

[a]Differentiation between layers based upon visual observation. Accurate classification of specific layer type (base, subbase, subgrade) was not possible because of little evident distinction in material type.

Table 3. Lowered tire pressures defined for typical axle loads and vehicle speeds[a]

Axle	*Axle Loads (lb)* Empty	Loaded	*Tire Pressures (psi)* Empty	Loaded
Steering	9,450	12,583	54	54
Driving			25	40
Front	7,508	19,200		
Rear	6,758	18,383		
Total	23,716	50,166		

[a]Average for six trucks.

With lowered tire pressures, this same road did not show any evidence of potholing until 3 weeks into normal hauling operations. Spot blading of the rougher sections was required 3 days thereafter. Potholes developed only in locations having a history of this problem.

Although lowered tire pressure did not eliminate potholing, it did delay the development and reduce the severity of the problem. During the lowered pressure runs, pothole growth was one-dimensional, parallel to the direction of vehicle travel. Both the width and depth of potholes remained relatively constant. Unlike the sharp, abrupt edges common to potholes subject to normal tire pressures, the edges of the potholes that developed during lowered pressure were smooth and well rounded. The shallow, less rough potholes provided for a much smoother ride for the drivers.

On February 3, all the trucks began running high tire pressures (90 psi in all tires). The high pressure phase was scheduled to continue until the road crew foreman felt that the road surface had deteriorated to the point that road maintenance was required. After the second day of hauling with high pressures, the potholes appeared to "shrink"in size, becoming deeper and wider while decreasing in length. The drivers complained of a rougher ride. A careful observation revealed that a significant number of new potholes had developed and that both the old and new potholes had sharp, abrupt edges. After only 3 days of hauling with high tire pressures, road damage was significant enough that all trucks returned to lowered pressures (see figures 7a and 7b).

Lowered tire pressures were used for 4 days to evaluate whether or not this would heal the aggregate road surface in lieu of grading. Potholes continued to develop. Cones were set up on some of the rougher segments to compel trucks to drive through the potholes. Lowered pressures did not seem to heal the road surface. According to Elder, some segments became so rough that trucks almost slowed to a stop to ease through the potholes.

The haul road required two bladings to return it to decent shape. Hauling continued using lowered tire pressures. For the 2 weeks following the last blading, the road surface remained relatively dry, and no significant road surface damage was observed. During the third week, however, a heavy rainfall resumed, and potholes became so severe that the test was halted for spot maintenance. The results of this test indicate that potholing is reduced by using lowered tire pressure. However, lowered tire pressure apparently will not heal roads such as these, where subgrade damage already has occurred and heavy rainfalls have caused subgrade weakening.

Table 4. Summary of total loads and haul miles

Truck #	*Total Loads* High Pressure	Lowered Pressure	*Total Haul Miles* High Pressure	Lowered Pressure	Total Miles
3940	16	174	418	3,247	5,967
4610	29	124	529	2,265	5,417
5247	14	180	463	3,031	6,262
4957	28	145	625	2,558	5,082
4956	12	250	324	4,227	7,152
1641	22	196	567	3,214	5,703
Total	121	1,069	2,926	18,542	35,583
Average	20	178	488	3,090	5,931

Table 5. Fuel consumption comparison

Truck #	Fuel Consumption (gal/mi) Test Program[a] (1/7/87-3/26/87)	Previous Year[a] (1/86-3/86)
1641	3.94	4.44[b]
4956	5.42	5.43
4957	4.74	6.34
5247	5.12	4.49
4610	5.44	5.65
3940	5.49	Not Available

[a]Average of 3 months.
[b]In August of 1986, the engine was changed from a 290 hp to a 350 hp. This may account, in part, for the increase in fuel consumption during this test program.

CTI System

Characteristics

The prototype CTI system used during this test program was developed and installed by Hodges Transportation Incorporated at the Nevada Automotive Testing Center in Carson City, Nevada. This particular external system regulates air pressure in the tires with pneumatic control valves (figure 8). External rotating seal joints are mounted on the center of the wheel axle to allow the air to flow from a stationary air line to a rotating wheel (figure 9). A cab control box, equipped with a pressure gauge, enables the driver to regulate the pressure in each axle and actuate the main control system.

On most trucks, the standard compressor size is 18 cubic feet per minute, which is usually sufficient for operating the CTI system, and no special or separate compressor is used. The compressor on the truck in this test, however, was only 12 cubic feet per minute, which was inadequate for this operation. A 17.5-cubic-feet-per-minute compressor was purchased and installed. To ensure that the brake system had priority for the air supply, a priority valve was installed.

Operation

Prior to testing, the truck traveled approximately 2,500 miles with lowered tire pressures, adjusted with the CTI onboard system (an additional 4,200 miles during testing). The truck had lowered tire pressure under both dry and muddy road surface conditions and on a variety of road surface types—pit run, black top, crushed aggregate, and native. Both prior to and during field testing, no tire damage was reported.

Rates of inflation and deflation vary for the CTI system and depend on the capacity of the air reservoir. With a 17.5-cubic-feet-per-minute reservoir installed, the rates of inflation and deflation for this vehicle varied between 2 and 6 minutes:

Rate (min.)	psi
3	40 to 25
2	25 to 40
6 per axle	40 to 100

For the 6-minute rate, the driver chose to inflate one axle at a time because it required over 30 minutes to inflate all axles simultaneously.

Figure 6. Formation of water rivulets on Road 2310.

Figure 7a. Section of Road 2310 showing minor evidence of potholing after 16 days of haul using lowered tire pressure.

Performance

Overall, the CTI system functioned well throughout the course of testing; only one instance of failure was reported. On January 13, the rotating joint on the right rear axle broke while the truck was on the highway, letting the air out of the four tires on the rear axle. All four tires were reinflated on the truck. The truck was driven back to the Quinault District shop for repair.

Glen Nyberg, test engineer at the Nevada Automotive Testing Center, investigated the failure of the rotary joint. It is possible that the unit was hit by a rock when loading the pit run gravel. Although the unit was damaged, total failure did not occur until tire pressure was raised to 90 psi for on-highway travel. The failure was noted by the driver 4 to 5 miles after raising tire pressure.

While disassembling the rotary joints, both the brass plugs and air inlet ports showed signs of emulsification, frothiness, and moisture (white grease was tan, while brown grease was black). The unpressurized areas showed signs of more moisture than the pressurized areas. According to Nyberg, moisture in the unpressurized areas could have been caused by high pressure washer use, the wet and humid operation conditions, and installment of large seals to prevent internal air leaking to the atmosphere.

Unpressurized areas are exposed to moisture and dirt, so an air dryer and filter were installed on the vehicle prior to replacing the damaged rotary joint. The Forest was advised not to use a pressure washer on the joints.

Precautions were taken to prevent the CTI components from freezing. The air reservoir was drained each night and the swivel joints covered. The driver

Figure 7b. Same section of road shown in Figure 7a after 3 days of haul using high tire pressure; pothole problem has increased significantly.

suggested that the control box be mounted on the front dash rather than on the floor to keep his focus on the road.

In general, the driver commented that he certainly would use a permanent CTI system if it were installed on his truck. After the test program was completed, the system remained on the truck and is currently being used under normal working operations.

Evaluation Of Tires

Following the field testing, eight recapped 11R24.5 radial tires were installed on the center and rear axles of each of two Quinault District vehicles. These tires had been run on the Boise National Forest CTI test in the fall of 1986. They had been inspected for internal carcass damage, then recapped.

One set of tires (including six new and four recapped) will be run at normal tire pressures and another set on the CTI-equipped vehicle at both lowered and normal pressures. Both trucks will be operated under similar working conditions. The Forest has agreed to keep records on the tires through the life of the tire carcasses. Figure 10 shows the type of information to be recorded.

Conclusions

The Olympic National Forest field test demonstrated the use and associated benefits of CTI systems and lowered tire pressure in Forest Service

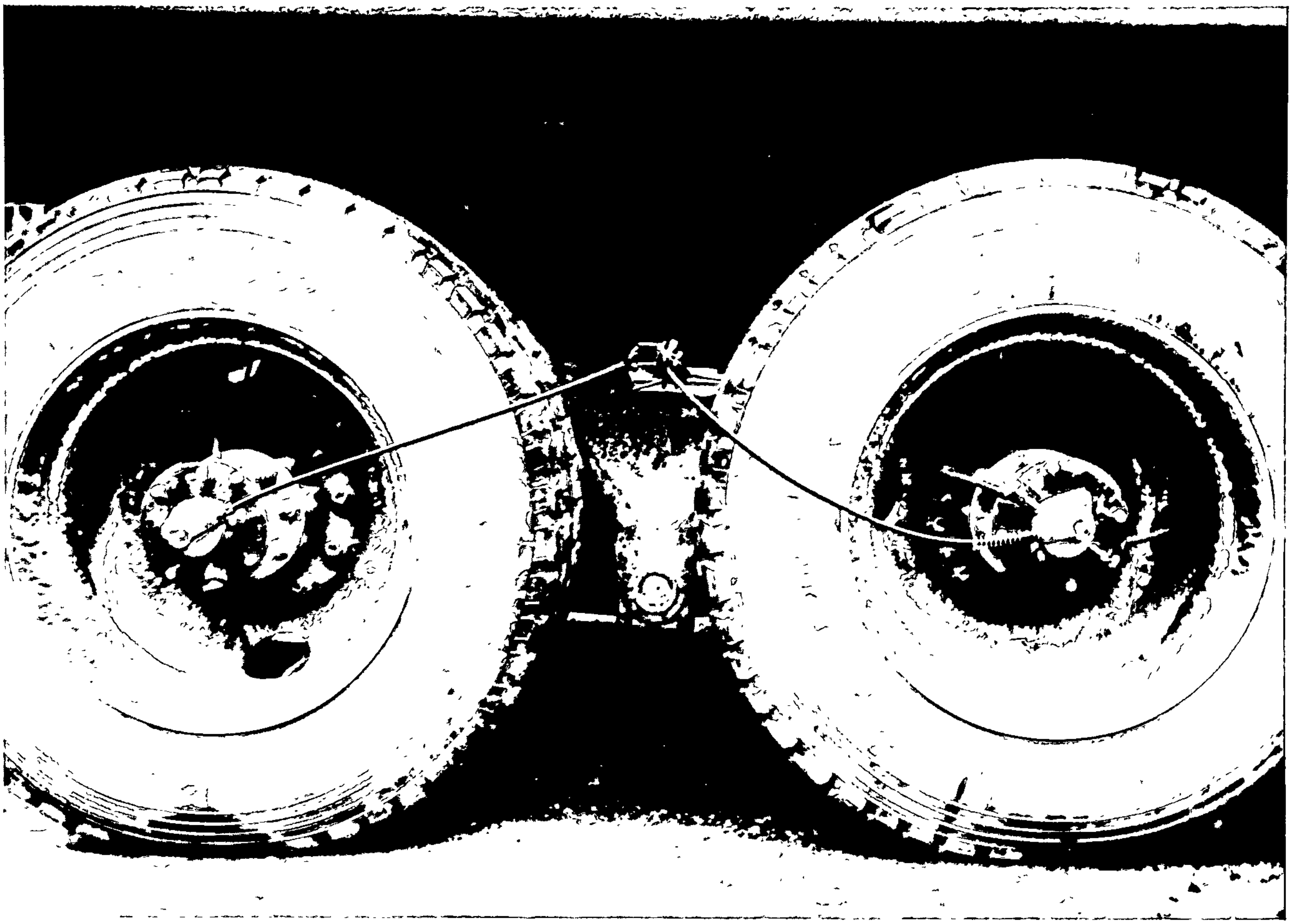


Figure 8. Air lines on dual tires for CTI system.

resurfacing projects. Six Forest Service 10-yard dump trucks used lowered tire pressure to haul rock for road resurfacing. One truck was equipped with an on-board CTI system to adjust tire pressures, while the other five trucks adjusted pressures manually at an airing station.

Throughout this test, opinions and observations regarding the effects of lowered tire pressures on the interrelationship among the road, the vehicle, and the driver were obtained. Limited quantitative measurements were made. Based on the test results reported here, the following conclusions can be drawn:

- Road maintenance was reduced significantly using lowered tire pressures. Normally, this haul route requires maintenance every 3 days during a rock haul, primarily because of pothole development. No maintenance was required during 3 weeks of hauling with lowered tire pressure.
- Lowered tire pressures had a definite healing effect on existing washboarding. Lowered tire pressure eliminated the formation of new washboarding.
- No tire damage was observed during the test period. Normally, this crew experiences five to seven flats per week. A substantial part of this improvement is attributed to the use of lowered tire pressures.
- The drivers felt that the trucks were more stable when dumping and spreading using lowered rather than high tire pressures.
- The drivers preferred the smoother ride and overall handling of the lowered pressure tires.
- The drivers experienced less back pain when using lowered tire pressure.

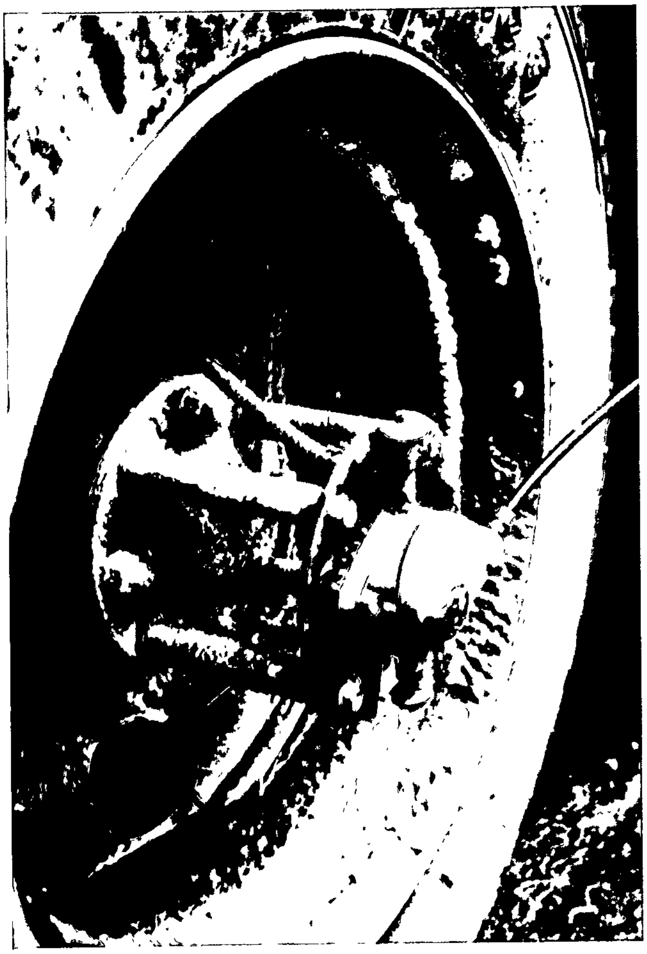


Figure 9. Rotating joint affixed to wheel hub for CTI system.

- The CTI system used performed satisfactorily without high maintenance costs.

In general, the field operational test demonstrated that the use of CTI and lowered tire pressures can be beneficial in road maintenance operations. The Forest staff are convinced that all their dump trucks should be equipped with CTI systems.

Recommendations

This test was one of a series to evaluate the effects of lowered tire pressures on the interrelationship among tires, vehicles, drivers, and the road surface. Specifically, it demonstrated that CTI and lowered tire pressures can be beneficial to Forest Service road crew operations. Based on the results of this test and comments made by Forest personnel, it is recommended that an action plan be developed to implement CTI technology into current Forest Service operations. Incorporating CTI technology into the *Transportation System Maintenance Handbook* would encourage better budgeting and use of limited available funds.

In addition, it is recommended that the Olympic National Forest continue to monitor and use the CTI system under normal working operations. Careful and continued monitoring of the performance of the tires installed on two of the vehicles is necessary to further evaluate the effects of lowered tire pressures on new and recapped tire performance.

INDIVIDUAL TIRE RECORD

SERIAL NO. ____________

MANUFACTURER ____________

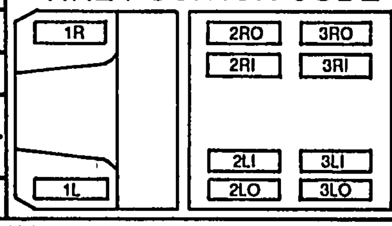
MODEL/SERIES ____________

TREAD TYPE ____________

SIZE ____________

DATE RECAPPED	RECAPPER	TREAD TYPE

TIRE POSITION CODE



MOUNT					DISMOUNT			
DATE / NTW	VEH. NO.	ODOMETER	POSITION	TREAD DEPTH	DATE / NTW	ODOMETER	TREAD DEPTH	REASON FOR REMOVAL
				/32"			/32"	
				/32"			/32"	
				/32"			/32"	
				/32"			/32"	
				/32"			/32"	
				/32"			/32"	
				/32"			/32"	
				/32"			/32"	
				/32"			/32"	
				/32"			/32"	
				/32"			/32"	

Figure 10. Example of format for individual tire records (10-wheel vehicle).

Appendix A—Test Plan

Central Tire Inflation Unstructured Test Program

Test Plan for Rock Haul
Olympic National Forest, Washington

Introduction And Scope

Commercial hauling trucks are traditionally operated with tire pressures of 90 to 110 psi. The design of these heavy vehicles and the roads to handle them have long been dictated by these high inflation pressures needed for loaded tires to survive. Damage to roads and the structural design required should be reduced when trucks operate with lowered tire pressure.

The scope of this test is to subjectively evaluate the effect of tire pressure on road surface deterioration, road maintenance, haul costs (i.e., truck maintenance, fuel consumption, round trip time, and tire life), and driver fatigue and injury. Limited measuring will be done to quantify these effects.

Objectives

The objectives for this test program are:

1. Demonstrate Central tire inflation (CTI) technology and benefits to the Forest Service and to the road construction and timber industry in the West, using as broad a scope of application as possible and being visible to a broad group of industry people.

2. Determine subjective benefits of lowered tire pressure with respect to road surfacing, road maintenance (washboard, dust, surf, replacement), haul cost (fuel, roundtrip time, tire cost, truck maintenance), and driver fatigue and injury.

Test Procedures

The test will consist of operating 10-yard dump trucks on this rock haul with varying tire pressures during a period beginning in January 1987, to determine the benefits of lowered tire pressure. Six trucks will be used to haul from this rock pit. Approximately 90 percent of the total passes will be operated at a low tire pressure, as determined to be safe by the project engineer for speeds, loads, and other conditions encountered. The remaining 10 percent of the passes will be operated with a tire pressure more commonly used (90-110 psi). The trucks shall be equipped with new radial 11R24.5 tires immediately prior to testing. Tire pressure shall be adjusted manually on five trucks and by using a CTI system on one truck to that appropriate for each phase of testing.

The road deterioration, haul cost effects, driver comfort, and vehicle handling characteristics will be determined for both the high and low tire pressure conditions. Drivers will be interviewed at the conclusion of each testing phase to record their perception of operational efficiency. Tests will be videotaped.

Up to 10 percent of the tires may be removed after testing for laboratory analysis. Any tires removed during testing will be replaced at the project expense. One (1) truck will be equipped with a CTI system (on or about November 1, 1986) and driven through January 1, 1987, to check that the system is functioning properly and provide for driver familiarization. Airing stations will be used for the remaining five (5) trucks at the rock pit to ensure that the driving axle tires are operated at constant deflection for the loaded and unloaded conditions (i.e., 41 psi loaded, 25 psi unloaded). Steering axle tires will be maintained at 55 psi for all operations during low pressure test phases.

The trucks will be parked overnight in Quinault, Washington. Before heading to Quinault, all trucks will be aired up to 90 psi, one truck by the CTI system and the other five (5) by an airing station at the junction of Roads 101 and 2220. Hauling will commence on or about January 7, 1987.

Specifics

The effects of changing tire pressures will be observed on Roads 2220 and 2302 and Road 2280, which has spot surfacing. This haul route was chosen specifically to test the effect of reduced tire pressure on sections of the route known to have a high surface moisture content and little surface strength. The moisture content of surfacing material will be measured throughout the tests.

Definitions

Test Road—The test roads shall consist of the following segments: Road 2310 from the pit (accessible by Roads 2310035 and 2310033) to the junction of Road 2302 (4.9 miles). Hauling continues along Road 2302 to the junction of Road 2220 (1.1 miles) and continues along Road 2220 to the junction of Road 2280 (1.2 miles). Hauling will then commence on Road 2280.

Segment—A portion of the test roads on which the test truck will travel at prescribed tire pressure with speeds monitored. Segments are designated by stations and road number.

Section—The portion of the road where the specific measurements/observations will be taken throughout the test. Sections are identified by letters.

Failure—The condition at which maintenance is required to continue haul.

I. Truck

I-A. Axle loads:

- Trucks will be fully loaded to approximately legal highway load limits.
- At the beginning of the test, loaded trucks will be weighed at Quinault, Washington.
- Trucks will be weighed so that each axle load can be determined.
- Weights will be recorded to nearest 100 pounds.
- Axle loads will be measured during test at discretion of the project engineer.
- Axle loads shall be recorded.

I-B. Tire pressure (cold):

- Tire pressures will be reduced daily at the junction of Roads 101 and 2220 in the morning. For the five (5) trucks not equipped with a CTI system, an airing station is needed to drop the tire pressures. Truck tires are to be reinflated at the rock pit throughout the day and at the junction in the evening prior to returning to Quinault.
- Tire pressure will be checked during the test as directed by the project engineer (daily or more frequently for the first 2 weeks, less frequently thereafter).
- Tire pressure will be recorded to the nearest psi.

I-C. Contact length, tire deflection, and tire print:

- After the tire pressure has been set at each pressure to be tested, the contact length, tire deflection, and tire print will be taken and recorded (one drive tire and one steering axle tire will be inked and set down on paper).
- Contact length shall be measured to the nearest half inch.
- Tire print will be taken by the project engineer in cooperation with the truck driver.

I-D. Driver impacts:

- The Ride Meter developed by the U.S. Army Corps of Engineers Waterway Experiment Station will be used to measure ride quality (driver comfort and injury). The Ride Meter will be operated using the recommended procedure. Each segment will also be measured immediately prior to the beginning of testing, during testing, and again immediately following the last trip.

I-E. Truck maintenance and repair:

- Accurate records will be kept of truck maintenance and repairs. Records will be made of any parts that fail, including type of failure, mileage of vehicle, miles of low pressure (including pressure) running, and operating conditions at failure. Downtime for repairs will also be recorded. A detailed history of the test will be kept for each truck. Historical records will be kept daily to record operating conditions, tire pressure, mileage, and other notable occurrences during the day. A thorough condition survey will be made of each vehicle immediately prior to the test and at the end of testing. If vehicles are used for non-project runs, a record will be made of conditions, tire pressure, maintenance, and so on, for the period of use off-site.

I-F. Fuel consumption:

- Fuel consumption will be measured for each vehicle. This will consist of recording the gallons and mileage, to the nearest tenth, each time the vehicle is refueled.

I-G. Tires:

- A record shall be made of any tire or rim damage, including conditions causing damage, type of damage, tire mileage, tire pressure, and other pertinent facts.

I-H. Vehicle speed:

- A radar gun (correlated with the vehicle's speedometer) will be used to determine each vehicle's speed through test segments and other designated segments of the haul route. During the first two weeks of the tests, measurements will be made daily for each vehicle to determine average speeds for each vehicle/driver. This should be repeated each time the tire pressure used on any road segment is changed. During the remainder of the tests, the speed will be spotchecked as necessary when the driver or project engineer detects a change in average operating speeds for any segment (such as slowdowns for increased road roughness, increased speeds with low pressure, and road familiarity). The measurements must be adequate to establish operating speeds (average) for each vehicle on each road segment and to establish variations in those average speeds. Conditions causing slower or faster speeds should be subjectively determined by both the driver and project engineer and recorded with information on speed. Round-trip times should be measured for each vehicle. The driver should record clock time from leaving the junction of Roads 101 and 2220 to arriving at the pits, and leaving the pit and arriving at the junction for each trip. Vehicles operating with lowered pressure will be strictly limited to a maximum speed of 30 mph.

II. Road

II-A. Nuclear moisture/density reading:

- There is one reading per test section.
- Location of readings will be taken at a set location between cross-sections.
- Moisture readings will be recorded at the beginning and end of each phase of testing (verify with an oven dry sample).
- Density readings will be taken on the surface and 4-inch depth increments to a depth of 12 inches at the beginning of the test and at the end of each test phase.

II-B. Washboard pitch and depth:

- If the truck drivers or test personnel observe washboard corrugation, crest-to-crest pitch distance (to the nearest tenth of a foot) and total depth of washboarding corrugation (to the nearest hundredth of a foot) will be measured from a straight edge or taut string stretched across the crests. Measurements will commence when washboard appears and will be taken at the discretion of the project engineer.

II-C. Trip counts:

- Drivers' logs will indicate the daily number of trips.

II-D. Road maintenance:

- Accurate records will be kept of the amount and type of road maintenance required, if any, as well as the cost of these activities. Records will include the number of passes incurred at each tire pressure to require maintenance, soil type (surfacing and subgrade), soil moisture, and precipitation prior to maintenance.

II-E. Road materials:

- Soil tests will be made for each test segment prior to testing. These tests will include Atterberg limits, R-value, sieve analyses, and proctor (T99) for soils and surfacing materials.

III. General

III-A. Weather:

- Precipitation will be taken from daily weather observation.
- Wet bulb and dry bulb temperatures will be taken at the haul area.

III-B. Video:

- A color record of the test and its effect on the road will be made with videotapes.
- The footage will be selected to show road effects and observable truck effects. Successive footage at the same location will be used, when effective, to depict significant road and truck changes.

III-C. Photographs:

- All photographs taken of roads will include photo date and road location test section or milepost.

III-D. Qualitative evaluations:

- At the time tire pressures are changed and at the end of the test, the drivers and project engineer each will fill out a questionnaire to subjectively evaluate the effect of tire pressure on:

  —Truck handling and stability
  —Fuel economy
  —Road deterioration and/or improvement
  —Use of jake brake
  —Vehicle speed
  —Round-trip time
  —Performance on grade (±)
  —Tire life
  —Driver comfort
  —Washboarding
  —Use of differential lockout
  —Truck maintenance
  —Overall effectiveness
  —Performance on curves

Appendix B—Soil Characteristics (for test sections)

Section		% Passing											T-85				T-210		Proctor		Humphries	
Number	Layer	1.5"	1'	3/4	1/2	3/8	#4	#10	#40	#80	#200	T-100	Absorp.	Appar.	T-96	T-176	(F)	(C)	Max Dens.	Op. Mois.	Max Dens.	@ Pass 4
1	1	100	100	98	90	80	58	39	18	12	8.4	2.93				32	64					
	2	95	87	81	72	62	44	28	12	8	5.7	2.65				22	29					
	3	85	75	68	59	51	35	25	14	11	8.6					22	26	26				
2	1	100	100	99	93	84	60	42	20	13	9.5	2.9				30	49					
	2	72	63	56	45	38	26	18	11	8	6.2	NA	5	2.75	23	25	27	17			139	47
	3																					
3	1	100	100	98	91	84	63	42	21	14	10.1	2.88		2.79	11	38	45	68			153	46
	2	91	79	64	46	34	19	13	6	4	2.7	2.75				24	23	2			129	46
	3	93	84	81	77	73	64	49	35	32	28.0											
4	1	100	99	98	92	83	60	40	18	12	8.7	2.78				37 >39	57	74			154	46
		100	99	94	81	71	50	32	15	9	2.0	2.87				41						
	2	100	99	96	86	75	54	36	19	15	11		5	2.75	23	21 >23					139	47
		72	63	56	45	38	26	18	11	8	6.2					25	29	17				
	3	72	63	56	45	38	26	18	11	8	6.2	NA	5	2.75	23	25	27		112	19.3	139	47
			86	79	73	66	49	32	15	9	5.7							17				
5	1	100	99	97	90	80	57	37	15	10	7.5	2.9		2.84	12	35	51	65			148	46
				95	83	71	48	32	19	15	11.8					26	42					
	2	72	63	56	45	38	26	18	11	8	6.2	NA	5	2.75	24	25	27	17	128.4	12.4	138	46
		85		71	61	53	38	27	15	11	7.8		3.1	2.68		27	23	21				
	3																					
6	1	100	99	97	90	79	55	39	19	13	10.4					27	50					
	2	99	96	89	76	63	39	26	16	12	9.1	2.79				17	23					
	3	91	89	85	84	81	72	59	22/33	17	11.9	2.63										

Appendix C—Truck Condition Surveys

USDA Forest Service Forms 7100-4a (1/78) Mechanical Inspection of Automotive Equipment

FS No.

1641
3940
4610
4956
4957
5247

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

MECHANICAL INSPECTION OF AUTOMOTIVE EQUIPMENT

(Reference FSM 7130)

1. CHARGE TO: Quinalt CTI Test Rock Job	2. UNIT NUMBER: Class 381	3. MAKE AND TYPE: 73 D-Reo Dump 10 c.y.	
	4. EQUIPMENT (FS) NO.: 1641	5. METER READING: 7,199 hours, 189689 miles	6. DATE INSPECTED: 1/6/87
7. MAINTENANCE ASSIGNED TO:	8. TYPE OF INSPECTION (X appropriate box): ☐ INITIAL SERVICE ☐ ANNUAL ☒ OTHER (Specify) preuse		

9. CODES

R - REPLACE X - REPAIR A - ADJUST V - CHECKLIST OK S - SERVICE L - LUBRICATE

10. INSPECTION LIST

PRE-INSPECTION (If needed)	CODE	ROAD TEST	CODE	UNDER HOOD	CODE
CLEAN VEHICLE EXTERIOR	✓	BRAKE - PARKING	✓	WIRING	
CLEAN VEHICLE INTERIOR	✓	FOOT BRAKE	✓	MANIFOLD HEAT VALVE	—
CLEAN ENGINE	✓	STEERING	✓	IGNITION SYSTEM	—
		STARTER	✓	SPARK PLUGS	—
VEHICLE EXTERIOR		CONTROLS	✓	FUEL LINES	✓
PAINT Fair	✓	GAUGES	✓	FUEL PUMP	✓
DECALS	✓	SWITCHES	✓	CARBURETOR	—
WINCH	—	NOISES	✓	MOTOR MOUNTS	✓
BUMPER	✓	CLUTCH	✓	ENGINE CONDITION	✓
FENDERS	✓	BACK-UP ALARM	✓	ALL BELTS	✓
CAB	✓	**UNDER VEHICLE**		MASTER CYLINDERS - Level	—
BODY, BED OR RACK	✓	STEERING GEAR	✓	FUEL FILTER	✓
TIRE CARRIER	—	KING PINS OR BALL JOINTS	✓	**OPERATION**	
TRAILER HITCH (Adequate)	X	TURN STOPS	✓	CHASSIS LUB	✓
MIRRORS - Tight (Adequate)	✓	TIE ROD	✓	OIL CHANGE	✓
LICENSE PLATES	✓	AXLE JOINTS (4 x 4)	—	PCV VALVE	
		CAB MOUNTS Fair	X	OIL FILTER CHANGE	✓
IN CAB		SHOCK ABSORBERS	✓	AIR CLEANER	✓
DOORS	X	SUSPENSION (Front-Rear)	✓	COOLANT - PROTECTION	✓
GLASS	X	TIRES	✓	BATTERY	✓
MIRRORS	✓	WHEELS	✓	FRONT WHEEL BEARING LUB	✓
WIPERS	✓	BRAKE LINING	✓	DOOR LATCHES - LOCKS	X
WASHERS	✓	BRAKE CYLINDERS	✓	TRAILER PLUG - CONTROLS	✓
HEATER	✓	BRAKE LINES - CABLES	✓	AIR CONDITIONER SYSTEM	—
DEFROSTERS	✓	FRAME	X		
LIGHTS	✓	TRANSMISSION - LINES			
TURN SIGNALS	✓	TRANSFER CASE	—		
HORN	✓	DRIVE SHAFTS	✓		
SEAT CUSHIONS - TRACK	✓	U-JOINTS	✓		
SEAT BELTS	✓	DIFFERENTIAL - VENT	✓		
EXTINGUISHER	✓	EXHAUST SYSTEM	✓		
FIRST AID KIT - MOUNTED	✓	MUD FLAPS	✓		
LOG BOOK - ENTRIES	—				
JACK	✓				
LUG WRENCH	✓				
FLARES/REFLECTORS	✓				

11. REMARKS Driver side door hinges & latch worn, excessive slop. - door glass weather strip worn. Frame cross member crack. Hand hold on muffler shield weak. Foot hold on dump box right side weld broke. Trailer hitch valve sticks sometime.

12. INSPECTED BY (Signature)	13. FINAL ROAD TEST BY (Signature)	14. ENTERED IN UNIT SERVICE RECORD
[signature]		DATE (NAME)

7100-4a (1/78)

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

MECHANICAL INSPECTION OF AUTOMOTIVE EQUIPMENT

(Reference FSM 7130)

1. CHARGE TO: Quinalt CTI Test Rock job	2. UNIT NUMBER: Class 381	3. MAKE AND TYPE: 77 GMC General 10 cy Dump	
	4. EQUIPMENT (FS) NO.: 3940	5. METER READING: 5549 hrs 146,138 miles	6. DATE INSPECTED: 1/6/87
7. MAINTENANCE ASSIGNED TO:	8. TYPE OF INSPECTION (X appropriate box): ☐ INITIAL SERVICE ☐ ANNUAL ☒ OTHER (Specify) pre use		

9. CODES
R - REPLACE X - REPAIR A - ADJUST V - CHECKLIST OK S - SERVICE L - LUBRICATE

10. INSPECTION LIST

PRE-INSPECTION (If needed)	CODE	ROAD TEST	CODE	UNDER HOOD	CODE
CLEAN VEHICLE EXTERIOR	✓	BRAKE - PARKING	✓	WIRING	✓
CLEAN VEHICLE INTERIOR	✓	FOOT BRAKE	✓	MANIFOLD HEAT VALVE	—
CLEAN ENGINE	✓	STEERING	✓	IGNITION SYSTEM	—
		STARTER	✓	SPARK PLUGS	—
VEHICLE EXTERIOR		CONTROLS	✓	FUEL LINES	✓
PAINT	✓	GAUGES	✓	FUEL PUMP	✓
DECALS	✓	SWITCHES	✓	CARBURETOR	—
WINCH	—	NOISES	✓	MOTOR MOUNTS	✓
BUMPER	✓	CLUTCH	✓	ENGINE CONDITION	✓
FENDERS	✓	BACK-UP ALARM	X	ALL BELTS	✓
CAB	✓	**UNDER VEHICLE**		MASTER CYLINDERS - Level	—
BODY, BED OR RACK Fair	✓	STEERING GEAR	✓	FUEL FILTER	✓
TIRE CARRIER	—	KING PINS OR BALL JOINTS	✓	**OPERATION**	
TRAILER HITCH (Adequate)	✓	TURN STOPS	✓	CHASSIS LUB	✓
MIRRORS - Tight (Adequate)	✓	TIE ROD	✓	OIL CHANGE	✓
LICENSE PLATES	✓	AXLE JOINTS (4 x 4)	—	PCV VALVE	—
		CAB MOUNTS	✓	OIL FILTER CHANGE	✓
IN CAB		SHOCK ABSORBERS	✓	AIR CLEANER	✓
DOORS	✓	SUSPENSION (Front-Rear)	✓	COOLANT - PROTECTION	✓
GLASS	✓	TIRES	✓	BATTERY	✓
MIRRORS	✓	WHEELS	✓	FRONT WHEEL BEARING LUB	✓
WIPERS	✓	BRAKE LINING	✓	DOOR LATCHES - LOCKS	✓
WASHERS	X	BRAKE CYLINDERS	✓	TRAILER PLUG - CONTROLS	✓
HEATER	✓	BRAKE LINES - CABLES	✓	AIR CONDITIONER SYSTEM	—
DEFROSTERS	✓	FRAME	✓		
LIGHTS	✓	TRANSMISSION - ~~LINES~~	✓		
TURN SIGNALS	✓	TRANSFER CASE	—		
HORN	X	DRIVE SHAFTS	✓		
SEAT CUSHIONS - TRACK Frair	X	U-JOINTS	✓		
SEAT BELTS	✓	DIFFERENTIAL - VENT	✓		
EXTINGUISHER	✓	EXHAUST SYSTEM	X		
FIRST AID KIT - MOUNTED	✓	MUD FLAPS			
LOG BOOK - ENTRIES	—				
JACK	✓				
LUG WRENCH	✓				
FLARES/REFLECTORS	✓				

11. REMARKS Top of washer container rusted out. electric horn don't work. Drivers seat bracket broke - cushion fair. no backup alarm (CENTER TANDEM DRIVELINE DUST COVER STRIPPED, split on EXHAUST head PIPE)

12. INSPECTED BY (Signature)	13. FINAL ROAD TEST BY (Signature)	14. ENTERED IN UNIT SERVICE RECORD	
[signature]		DATE	(NAME)

7100-4a (1/78)

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

MECHANICAL INSPECTION OF AUTOMOTIVE EQUIPMENT

(Reference FSM 7130)

1. CHARGE TO: Quinalt CTI Test Rockjob

2. UNIT NUMBER: class 381

3. MAKE AND TYPE: 10CY 78 GMC Brigadier Dump

4. EQUIPMENT (FS) NO.: 4610

5. METER READING: 2928.3 hrs 63,035 miles

6. DATE INSPECTED: 1/6/87

7. MAINTENANCE ASSIGNED TO:

8. TYPE OF INSPECTION (X appropriate box): ☐ INITIAL SERVICE ☐ ANNUAL ☒ OTHER (Specify) Pre use

9. CODES: R - REPLACE X - REPAIR A - ADJUST V - CHECKLIST OK S - SERVICE L - LUBRICATE

10. INSPECTION LIST

PRE-INSPECTION (If needed)	CODE
CLEAN VEHICLE EXTERIOR	✓
CLEAN VEHICLE INTERIOR	✓
CLEAN ENGINE	✓
VEHICLE EXTERIOR	
PAINT	✓
DECALS	✓
WINCH	—
BUMPER	✓
FENDERS	X
CAB	✓
BODY, BED OR RACK	✓
TIRE CARRIER	—
TRAILER HITCH (Adequate)	✓
MIRRORS - Tight (Adequate)	✓
LICENSE PLATES	✓
IN CAB	
DOORS	✓
GLASS	✓
MIRRORS	✓
WIPERS	✓
WASHERS	✓
HEATER	✓
DEFROSTERS	✓
LIGHTS	X
TURN SIGNALS	✓
HORN	✓
SEAT CUSHIONS - TRACK	✓
SEAT BELTS	✓
EXTINGUISHER	✓
FIRST AID KIT - MOUNTED	✓
LOG BOOK - ENTRIES	—
JACK	✓
LUG WRENCH	✓
FLARES/REFLECTORS	✓

ROAD TEST	CODE
BRAKE - PARKING	✓
FOOT BRAKE	✓
STEERING	X
STARTER	✓
CONTROLS	✓
GAUGES	✓
SWITCHES	✓
NOISES	✓
CLUTCH	✓
BACK-UP ALARM	X
UNDER VEHICLE	
STEERING GEAR SEAL leaks	
KING PINS OR BALL JOINTS	✓
TURN STOPS	✓
TIE ROD	✓
AXLE JOINTS (4 x 4)	—
CAB MOUNTS	✓
SHOCK ABSORBERS	✓
SUSPENSION (Front-Rear)	✓
TIRES	✓
WHEELS	✓
BRAKE LINING	✓
BRAKE CYLINDERS	✓
BRAKE LINES - CABLES	✓
FRAME	✓
TRANSMISSION - ~~LINES~~	✓
TRANSFER CASE	—
DRIVE SHAFTS	✓
U-JOINTS	✓
DIFFERENTIAL - VENT	✓
EXHAUST SYSTEM	✓
MUD FLAPS	✓

UNDER HOOD	CODE
WIRING	✓
MANIFOLD HEAT VALVE	—
IGNITION SYSTEM	—
SPARK PLUGS	—
FUEL LINES	✓
FUEL PUMP	✓
CARBURETOR	—
MOTOR MOUNTS	✓
ENGINE CONDITION	✓
ALL BELTS	✓
MASTER CYLINDERS - Level	
FUEL FILTER	
OPERATION	
CHASSIS LUB	✓
OIL CHANGE	X
PCV VALVE	✓
OIL FILTER CHANGE	
AIR CLEANER	
COOLANT - PROTECTION	✓
BATTERY	✓
FRONT WHEEL BEARING LUB	✓
DOOR LATCHES - LOCKS	✓
TRAILER PLUG - CONTROLS	✓
AIR CONDITIONER SYSTEM	

11. REMARKS: left front park light wiring need work - light out. Power steering main cylinder leaks. Backup alarm out. Crack in fibreglass on left where fender meets hood. needs oil change lube finder oil seal leak.

12. INSPECTED BY (Signature): [signature]

13. FINAL ROAD TEST BY (Signature):

14. ENTERED IN UNIT SERVICE RECORD: DATE (NAME)

7100-4a (1/78)

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

MECHANICAL INSPECTION OF AUTOMOTIVE EQUIPMENT

(Reference FSM 7130)

1. CHARGE TO	2. UNIT NUMBER	3. MAKE AND TYPE	
Quinalt CTI Test Rock job	Class 381	80 Auto Car 10 cy Dump	
	4. EQUIPMENT (FS) NO. 4956	5. METER READING 5,612.6 hours 98,719 miles	6. DATE INSPECTED 1/6/87
7. MAINTENANCE ASSIGNED TO:	8. TYPE OF INSPECTION (X appropriate box) ☐ INITIAL SERVICE ☐ ANNUAL ☒ OTHER (Specify) pre use		

9. CODES

R - REPLACE X - REPAIR A - ADJUST V - CHECKLIST OK S - SERVICE L - LUBRICATE

10. INSPECTION LIST

PRE-INSPECTION *(if needed)*	CODE
CLEAN VEHICLE EXTERIOR	✓
CLEAN VEHICLE INTERIOR	✓
CLEAN ENGINE	✓
VEHICLE EXTERIOR	
PAINT	X
DECALS	✓
WINCH	—
BUMPER	✓
FENDERS	✓
CAB	X
BODY, BED OR RACK	X
TIRE CARRIER	—
TRAILER HITCH *(Adequate)*	✓
MIRRORS - Tight *(Adequate)*	✓
LICENSE PLATES	✓
IN CAB	
DOORS	X
GLASS	✓
MIRRORS	✓
WIPERS	✓
WASHERS	✓
HEATER	✓
DEFROSTERS	✓
LIGHTS	X
TURN SIGNALS	✓
HORN	X
SEAT CUSHIONS - TRACK	✓
SEAT BELTS	✓
EXTINGUISHER	✓
FIRST AID KIT - MOUNTED	✓
LOG BOOK - ENTRIES	—
JACK	✓
LUG WRENCH	✓
FLARES/REFLECTORS	✓

ROAD TEST	CODE
BRAKE - ~~PARKING~~ maxi	✓
FOOT BRAKE	✓
STEERING	✓
STARTER	✓
CONTROLS	✓
GAUGES	X
SWITCHES	✓
NOISES	✓
CLUTCH	✓
BACK-UP ALARM	✓
UNDER VEHICLE	
STEERING GEAR	L
KING PINS OR BALL JOINTS	L
TURN STOPS	L
TIE ROD	L
AXLE JOINTS (4 x 4)	—
CAB MOUNTS	L
SHOCK ABSORBERS	L
SUSPENSION *(Front-Rear)*	
TIRES	✓
WHEELS	✓
BRAKE LINING	L
BRAKE CYLINDERS	L
BRAKE LINES - CABLES	L
FRAME	L
TRANSMISSION - ~~LINES~~	L
TRANSFER CASE	—
DRIVE SHAFTS	L
U-JOINTS	L
DIFFERENTIAL - VENT	L
EXHAUST SYSTEM	✓
MUD FLAPS	✓

UNDER HOOD	CODE
WIRING	L
MANIFOLD HEAT VALVE	—
IGNITION SYSTEM	—
SPARK PLUGS	—
FUEL LINES	L
FUEL PUMP	L
CARBURETOR	—
MOTOR MOUNTS	L
ENGINE CONDITION	L
ALL BELTS	L
MASTER CYLINDERS - Level	—
FUEL FILTER	L
OPERATION	
CHASSIS LUB	L
OIL CHANGE	L
PCV VALVE	L
OIL FILTER CHANGE	L
AIR CLEANER	L
COOLANT - PROTECTION	L
BATTERY	L
FRONT WHEEL BEARING LUB	L
DOOR LATCHES - LOCKS	L
TRAILER PLUG - CONTROLS	L
AIR CONDITIONER SYSTEM	

11. REMARKS Tool box needs new hinge - new paint on top of hood blistered - window on drivers door loose - needs new felt. - mirror heater switch inoperable at times - 3 gauge switchin in dash are out. - speedometer could be 2 miles per hour slow - roof leaks when heavy rain. - electric horn don't work

12. INSPECTED BY *(Signature)*	13. FINAL ROAD TEST BY *(Signature)*	14. ENTERED IN UNIT SERVICE RECORD
[signature]		DATE (NAME)

7100-4a (1/78)

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

MECHANICAL INSPECTION OF AUTOMOTIVE EQUIPMENT

(*Reference FSM 7130*)

1. CHARGE TO: Quinalt ITT Test Rock job
2. UNIT NUMBER: Class 381
3. MAKE AND TYPE: 80 AutoCar KM64F 10 CY Dump
4. EQUIPMENT (FS) NO. 4957
5. METER READING: 5964 hours 70483 miles
6. DATE INSPECTED: 1/6/87
7. MAINTENANCE ASSIGNED TO:
8. TYPE OF INSPECTION (*X appropriate box*): ☐ INITIAL SERVICE ☐ ANNUAL ☒ OTHER (*Specify*) pre use

9. CODES: R - REPLACE X - REPAIR A - ADJUST V - CHECKLIST OK S - SERVICE L - LUBRICATE

10. INSPECTION LIST

PRE-INSPECTION (*If needed*)	CODE
CLEAN VEHICLE EXTERIOR	✓
CLEAN VEHICLE INTERIOR	✓
CLEAN ENGINE	✓
VEHICLE EXTERIOR	
PAINT	✓
DECALS	✓
WINCH	—
BUMPER	✓
FENDERS	✓
CAB	✓
BODY, BED OR RACK	✓
TIRE CARRIER	—
TRAILER HITCH (*Adequate*)	✓
MIRRORS - Tight (*Adequate*)	✓
LICENSE PLATES	✓
IN CAB	
DOORS	✓
GLASS	✓
MIRRORS	✓
WIPERS	✓
WASHERS	✓
HEATER	✓
DEFROSTERS	✓
LIGHTS	X
TURN SIGNALS	✓
HORN	X
SEAT CUSHIONS - TRACK	✓
SEAT BELTS	✓
EXTINGUISHER	✓
FIRST AID KIT - MOUNTED	✓
LOG BOOK - ENTRIES	—
JACK	✓
LUG WRENCH	✓
FLARES/REFLECTORS	✓

ROAD TEST	CODE
BRAKE - PARKING	✓
FOOT BRAKE	✓
STEERING	✓
STARTER	✓
CONTROLS	✓
GAUGES	✓
SWITCHES	✓
NOISES	✓
CLUTCH	✓
BACK-UP ALARM	✓
UNDER VEHICLE	
STEERING GEAR	L
KING PINS OR BALL JOINTS	L
TURN STOPS	L
TIE ROD	L
AXLE JOINTS (4 x 4)	—
CAB MOUNTS	L
SHOCK ABSORBERS	L
SUSPENSION (*Front-Rear*)	L
TIRES	L
WHEELS	L
BRAKE LINING	L
BRAKE CYLINDERS	L
BRAKE LINES - CABLES	L
FRAME	L
TRANSMISSION - ~~LINES~~	L
TRANSFER CASE	—
DRIVE SHAFTS	L
U-JOINTS	L
DIFFERENTIAL - VENT	L
EXHAUST SYSTEM	L
MUD FLAPS	L

UNDER HOOD	CODE
WIRING	L
MANIFOLD HEAT VALVE	—
IGNITION SYSTEM	—
SPARK PLUGS	—
FUEL LINES	L
FUEL PUMP	L
CARBURETOR	—
MOTOR MOUNTS	L
ENGINE CONDITION	L
ALL BELTS	L
MASTER CYLINDERS - Level	—
FUEL FILTER	L
OPERATION	
CHASSIS LUB	X
OIL CHANGE	X
PCV VALVE	—
OIL FILTER CHANGE	✓
AIR CLEANER	✓
COOLANT - PROTECTION	✓
BATTERY	✓
FRONT WHEEL BEARING LUB	✓
DOOR LATCHES - LOCKS	✓
TRAILER PLUG - CONTROLS	✓
AIR CONDITIONER SYSTEM	—

11. REMARKS: One brake light out. Elec horn don't work. Needs oil & lube job

12. INSPECTED BY (*Signature*): [signature]

13. FINAL ROAD TEST BY (*Signature*):

14. ENTERED IN UNIT SERVICE RECORD
DATE ______ (NAME) ______

7100-4a (1/78)

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

MECHANICAL INSPECTION OF AUTOMOTIVE EQUIPMENT

(Reference FSM 7130)

10 CY

1. CHARGE TO	2. UNIT NUMBER	3. MAKE AND TYPE	
Quinalt CTI Test Rock job	Class 381	79 International S2500 Dump	
	4. EQUIPMENT (FS) NO. 5247	5. METER READING 4720 hrs 083,441 mi	6. DATE INSPECTED 1/6/87
7. MAINTENANCE ASSIGNED TO:	8. TYPE OF INSPECTION (X appropriate box) ☐ INITIAL SERVICE ☐ ANNUAL ☒ OTHER (Specify) pre use		

9. CODES

R - REPLACE X - REPAIR A - ADJUST V - CHECKLIST OK S - SERVICE L - LUBRICATE

10. INSPECTION LIST

PRE-INSPECTION (If needed)	CODE
CLEAN VEHICLE EXTERIOR	✓
CLEAN VEHICLE INTERIOR	✓
CLEAN ENGINE	✓
VEHICLE EXTERIOR	
PAINT	✓
DECALS	✓
WINCH	—
BUMPER	✓
FENDERS	X
CAB	X
BODY, BED OR RACK	✓
TIRE CARRIER	—
TRAILER HITCH (Adequate)	✓
MIRRORS - Tight (Adequate)	✓
LICENSE PLATES	✓
IN CAB	
DOORS	✓
GLASS	✓
MIRRORS	✓
WIPERS	✓
WASHERS	✓
HEATER	✓
DEFROSTERS	✓
LIGHTS	✓
TURN SIGNALS	✓
HORN	✓
SEAT CUSHIONS - TRACK	✓
SEAT BELTS	✓
EXTINGUISHER	✓
FIRST AID KIT - MOUNTED	✓
LOG BOOK - ENTRIES	—
JACK	✓
LUG WRENCH	✓
FLARES/REFLECTORS	✓

ROAD TEST	CODE
BRAKE - PARKING	✓
FOOT BRAKE	✓
STEERING	✓
STARTER	✓
CONTROLS	✓
GAUGES	✓
SWITCHES	✓
NOISES	✓
CLUTCH	✓
BACK-UP ALARM	X
UNDER VEHICLE	
STEERING GEAR	—
KING PINS OR BALL JOINTS	—
TURN STOPS	—
TIE ROD	—
AXLE JOINTS (4 x 4)	—
CAB MOUNTS	—
SHOCK ABSORBERS	—
SUSPENSION (Front-Rear)	—
TIRES	—
WHEELS	—
BRAKE LINING	—
BRAKE CYLINDERS	—
BRAKE LINES - CABLES	—
FRAME	—
TRANSMISSION - ~~LINES~~	—
TRANSFER CASE	—
DRIVE SHAFTS	—
U-JOINTS	—
DIFFERENTIAL - VENT	X
EXHAUST SYSTEM	—
MUD FLAPS	—

UNDER HOOD	CODE
WIRING	—
MANIFOLD HEAT VALVE	—
IGNITION SYSTEM	—
SPARK PLUGS	—
FUEL LINES	—
FUEL PUMP	—
CARBURETOR	—
MOTOR MOUNTS	—
ENGINE CONDITION	—
ALL BELTS	—
MASTER CYLINDERS - Level	—
FUEL FILTER	—
OPERATION	
CHASSIS LUB	✓
OIL CHANGE	✓
PCV VALVE	—
OIL FILTER CHANGE	✓
AIR CLEANER	✓
COOLANT - PROTECTION	✓
BATTERY	✓
FRONT WHEEL BEARING LUB	✓
DOOR LATCHES - LOCKS	✓
TRAILER PLUG - CONTROLS	✓
AIR CONDITIONER SYSTEM	—

11. REMARKS Small crack in fiberglass left fender near bolt & at top of hood near windshield. No backup alarm. Diferential seal leak.

12 INSPECTED BY (Signature)	13. FINAL ROAD TEST BY (Signature)	14. ENTERED IN UNIT SERVICE RECORD
D [signature]		DATE (NAME)

7100-4a (1/78)