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Beyond "Empowerment Versus Constraint"

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There is currently much discussion of *empowering* employees to do their jobs, that is: The employees know their jobs best; we mustn't box them in with constraints of policies, targets, and direction; they need room to creatively adapt to on-the-ground needs and opportunity. Some managers, often accused of being dinosaurs, ask, "What about accountability, production, laws, and directions?"

Is the issue really empowerment versus constraint? Is it really either–or? Absolutely not! There is actually a higher philosophical plane, which I call "foundation," that makes empowerment versus constraint a moot issue.

Absolute empowerment would free employee creativity in all directions, even back to the roots of science and culture. The employee could invent alternatives to the wheel and the lever, hours in a day, or property rights. Obviously not practicable, no one is proposing this. Everyone actually builds on a foundation of science and culture, looking for ways to improve. Not that past science and culture are closed to review, but rather that focus and emphasis are upward and outward.

The Japanese didn't reinvent the concept of the automobile in taking the lead away from the United States. They creatively built upon a foundation of existing automotive and management technology to build a better car less expensively. There are many technical improvements, but it looks like a car, drives like a car, and meets U.S. environmental and safety requirements.

When we look at an attractive, smoothly functioning new building, we admire the creative freedom of the architect. We don't see and admire how the building is supported by its underground foundation. We don't see how the structure relates to foundations of engineering principles, building and zoning laws, and the budget and goals of the owner. The creative adaptation was unlimited; the architect was empowered upward and outward, not constrained by foundations. But all the elements of foundation are present.

The secretary doesn't need to reinvent the keyboard or develop a new letter format every time routine correspondence is produced. Certainly, the secretary should be aware of new systems and recommend improvements, but the focus is on producing better, faster correspondence using the foundation of the best available equipment and current direction.

Every day, in every walk of life, we can be empowered to grow from a foundation. We are not precluded from revisiting that foundation, but our energies and efforts focus on improvement. So it should be with policies, targets, and accountability. Yes, these can be misused to confine and constrain employees, but, more importantly, they can and should provide a solid foundation from which to focus employees' creative efforts upward and outward. The stronger this foundation, the more effectively we can achieve personal and organizational goals.

Central Tire Inflation: The USDA Forest Service Program

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Introduction

Since 1983, the USDA Forest Service has been working on a program to test the feasibility of and, if deemed appropriate, develop and implement central tire inflation (CTI) technology. CTI is a system, installed on a vehicle, that allows the driver to adjust tire pressure while the vehicle is in motion. With CTI, tire pressures can be varied to realize the maximum benefit for any given load, speed, and road condition. The program has made significant headway in pursuit of this goal. A review of progress may be of interest to others involved with low-volume road construction and maintenance or operators of commodity-hauling vehicles.

Why is a Government agency so interested in varying tire pressures? The Forest Service operates approximately 360,000 miles of road. The vast majority of this total consists of single-lane gravel and native surfaced roads. Our primary reasons for utilizing CTI are to reduce the thickness of rock aggregate necessary to support traffic loads (figure 1) and lessen road maintenance costs. The road construction and maintenance savings were estimated to be in excess of \$20 million annually.[1]

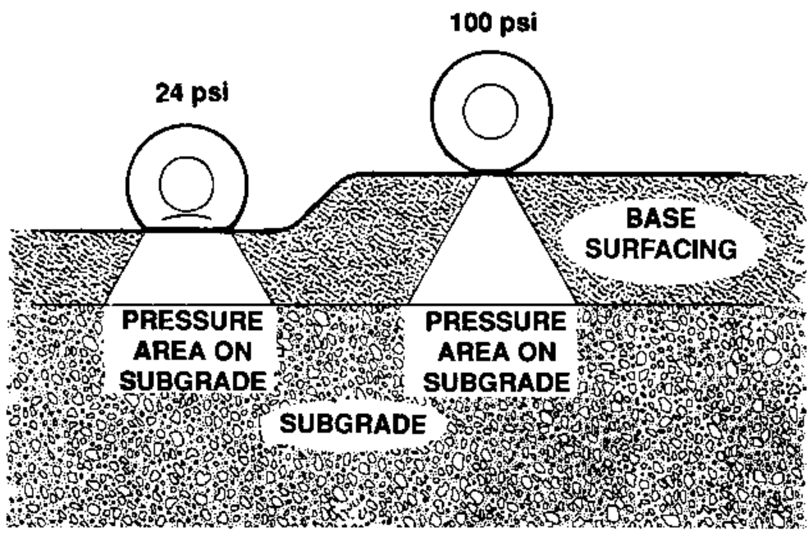

Figure 1.—Spreading the vehicle's load over a larger tire "footprint" lessens the required supporting material. Additional benefits include lengthier hauling seasons, increased vehicle mobility, and decreased truck maintenance, vibrations to drivers, and road surface damage and siltation.

Update on the CTI Program

In August 1992, I presented a paper to the annual meeting of the Council on Forest Engineering in Hot Springs, Arkansas. It occurred to me that a lot has happened with CTI during the past few years, and it ought to be shared with more individuals within the Agency. With that goal in mind, this paper is submitted in its entirety.

Most of the readers of *Engineering Field Notes* have, no doubt, heard of CTI, but most probably don't interact with it very much, if at all. This may change shortly because our Forest Service efforts have resulted in a major truck components manufacturer, Eaton Corporation, working toward a commercial product in 1993. The article that follows gives a broad overview of the program and serves to highlight its changing nature. We are now shifting away from the development of a system and toward learning more about the benefits associated with its use.

History

CTI technology is not new. In World War II, both the United States and the Soviet Union had CTI systems. These early systems were fairly crude, consisting of manually-valved air lines to control tire air pressure. Because of its highly developed system of paved highways, the United States dropped the technology until the military need for increased mobility and rapid deployment became critical. Today, there are thousands of U.S. military vehicles with CTI systems, including 5-ton trucks, heavy equipment transports, palletized load carriers, and high-mobility tactical vehicles. The Forest Service continues to work closely with the U.S. Army Tank-Automotive Command on this technology.

On the commercial side, very few vehicles employ CTI systems. The few notable exceptions include experimentation with sanitation vehicles for landfill mobility and airport crash/rescue fire engines needing mobility to access areas off paved surfaces.

Program Description

In order to commence a study of this magnitude, a detailed plan was developed. The technology implementation plan was labeled "Operation Bigfoot" after the enlarged tire footprint associated with CTI vehicles. It established the principal areas for work concentration. The 14 planned actions were:

(1) Establish Forest Service Regional Coordinators

(2) Develop a list of key industry contacts

(3) Coordinate safety aspects

(4) Develop contract language for use of CTI systems

(5) Identify guidelines for providing CTI allowances for timber purchasers

(6) Develop an informational video and printed materials

(7) Provide information to our field units on how to implement the plan

(8) Develop specifications to equip Government vehicles with CTI systems

(9) Publish Regional timber appraisal guidelines

(10) Develop an economic model for the utilization of this technology

(11) Educate our fleet employees on the benefits

(12) Retrofit existing government vehicles where appropriate

(13) Establish demonstration projects in different areas of the Nation

(14) Coordinate with Federal, State, and local road agencies.

Additionally, a national steering committee was established to help anticipate problem areas during plan implementation. This group included members of the following organizations:

- Michelin Tire Corporation
- Schaub-Ellison Company (tire dealer)
- American Pulpwood Association
- U.S. Army Tank-Automotive Command
- Weyerhaeuser Company
- Bandag, Incorporated (tire retreader)
- Washington Log Truckers Conference
- Rockwell International (axle producer)
- National Forest Products Association.

Eaton Corporation and Goodyear Tire and Rubber Company have participated during the last several years but are not formal members. This steering committee has met about twice a year for the past 4 years and has provided indispensable information regarding industry operations and accepted practices for developments in the subject area.

Perhaps the best way to describe the total program is to address the two separate areas of primary effort, which are:

(1) ***System Development:*** Working with system manufacturers to develop a reliable system, gaining acceptance by the tire industry, and progressing toward compatibility of accepted systems.

(2) ***Economics:*** Developing an understanding of where the technology will work and defining its limitations. In order to make decisions on whether to use CTI, a proper understanding of the true benefits must be acquired.

System Development

The area of system development has seen greater advances in bringing CTI technology to the end-user than the economic portion of the program. Early prototype systems were constructed from available mechanical parts and combined with an electronic control unit manufactured by Eltek, Incorporated, of Grand Rapids, Michigan. These systems were installed on a variety of vehicles, including off-highway rock haul trucks in Alaska and Forest Service dump trucks (figure 2). Additional systems were developed by TISCO, Incorporated, of Pomona, California. The TISCO systems were installed on 18-wheel log trucks in the Darrington, Washington, area. Various other efforts are underway in Canada, Australia, and New Zealand.[2]

These systems employed the vehicle's air compressor and a manifold assembly to route the air to the wheel ends. Steering and trailer axles were drilled so air could be routed internally to the wheel-end hardware. Powered axles (drive axles) had to utilize a rotating air seal with exterior hoses. These hoses have been a sore spot with vehicle owners and drivers because of the greater likelihood they could be damaged during hauling operations. Additionally, these exterior hoses had the appearance of a prototype rather than a finished system.

We achieved our most substantial breakthrough with contracts for the manufacture of preproduction CTI systems with Eaton Corporation, Kalamazoo, Michigan. Because Eaton is an axle manufacturer, they were able to install internal seals on their own axles without voiding any warranties or raising questions about compatibility.

Two contracts were awarded to Eaton, the first calling for 20 CTI systems to be produced. The first three systems were installed on Forest Service dump trucks for a trial evaluation. The emphasis then shifted to the private sector, with the remaining 17 installed on commodity-hauling vehicles operating on National Forest roads. We utilized a cooperative agreement, basically trading an installed CTI system for data on its reliability and performance. The second contract called for the production of 20 systems for Forest Service dump trucks only (figure 3). The two systems are essentially identical.

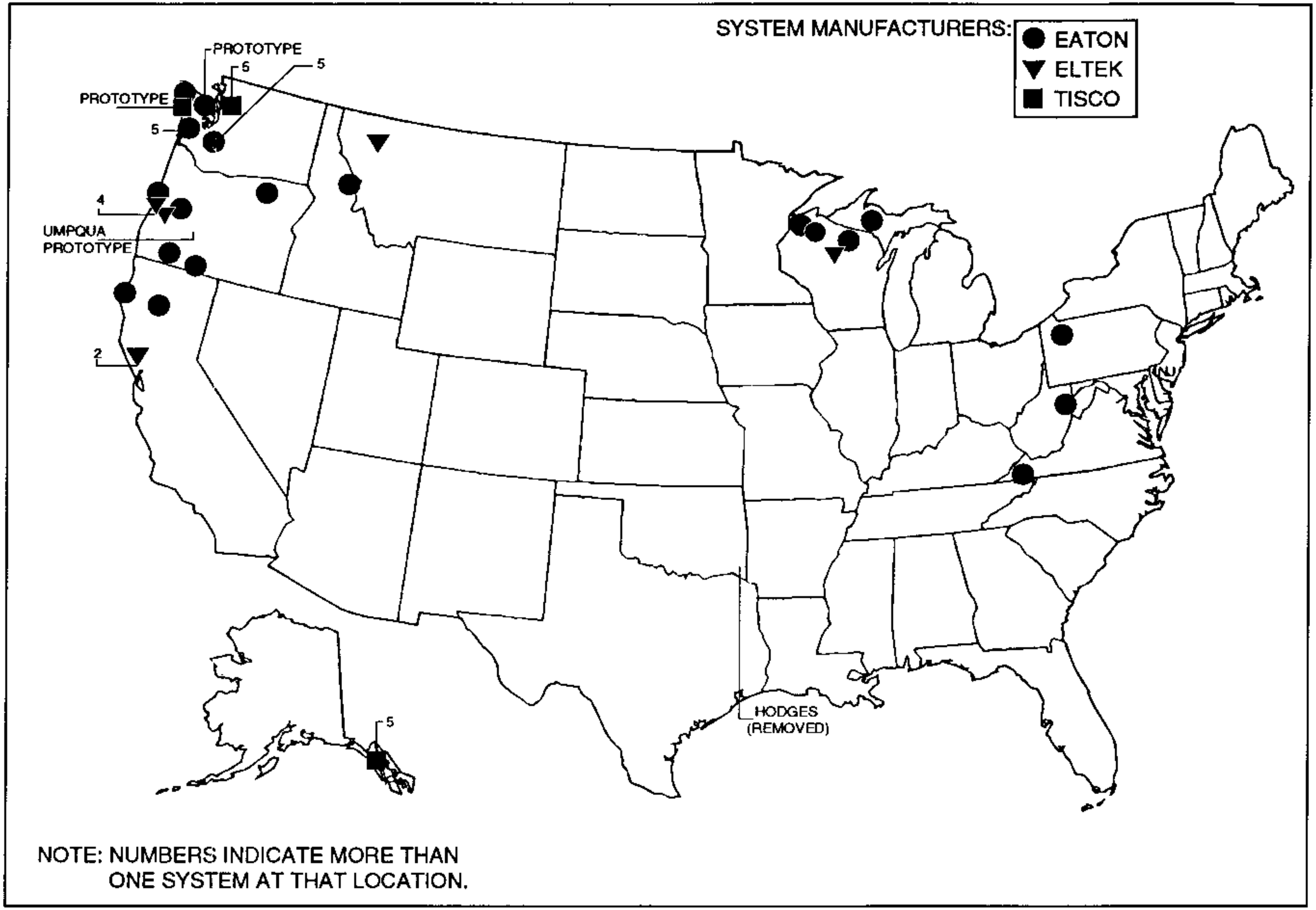

Figure 2.—CTI System installations through June 1, 1992.

Figure 3.—Forest Service dump truck with Eaton CTI system.

There are several major advantages associated with the new Eaton system. The systems are fully internal, meaning no hoses run exterior to the vehicle (figure 4). They employ a seal assembly (figure 5) that mates with their own axle and is fully compatible and warranted. Electronic programmable control panels enable fleet managers to establish tire pressures to suit their needs. These devices contain safeguards that will automatically inflate tires detected to be traveling in excess of preprogrammed speed constraints.

Another significant component of the program is the involvement of tire companies in assisting us in determining tire treadwear and carcass life. Goodyear Tire and Rubber Company and Michelin Corporation supplied tires for evaluation and tracked their performance in reduced pressure operation. Goodyear continues to operate a major test where they are monitoring some 250 tires in CTI service and in regular highway pressure service as a control group. Their test plan calls for X-ray holography of 11 R24.5 truck tires prior to installation and prior to each retreading and mounting. Treadwear measurements were also taken at appropriate time intervals. Each tire was uniquely branded so their technical personnel could determine the wheel position in which it was used. This systematic approach enabled them to follow each tire through actual log haul and gravel haul service, noting both treadwear rates and tire carcass survivability.

The Goodyear study indicated that treadwear differences were too small to make any real determination whether CTI had any effect.[3] The carcass life issue is being reviewed, but after two retread cycles on some of the test vehicles, there is no significant difference as far

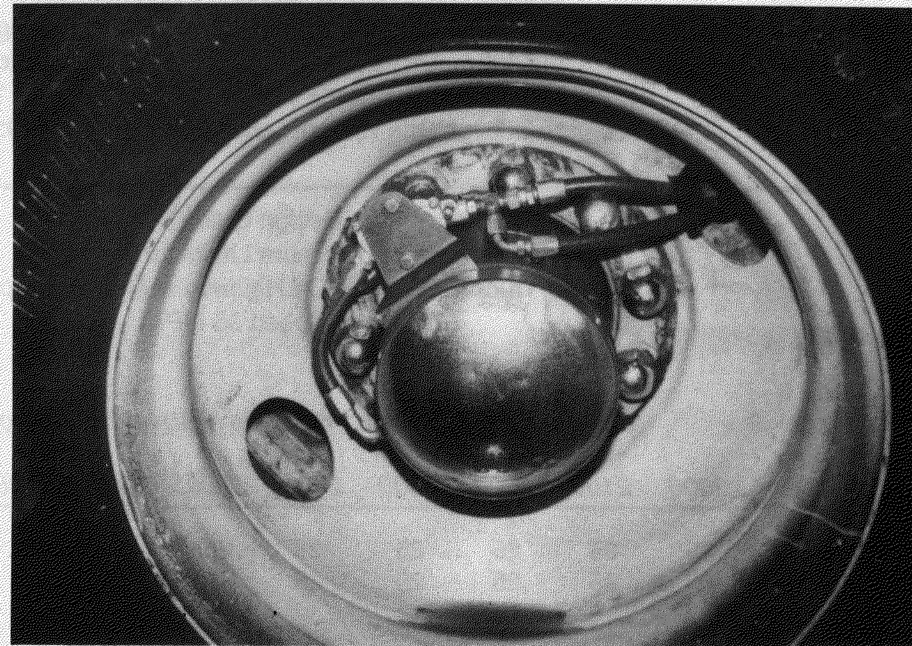

Figure 4.—Dump truck drive wheel with recessed wheel valve assembly.

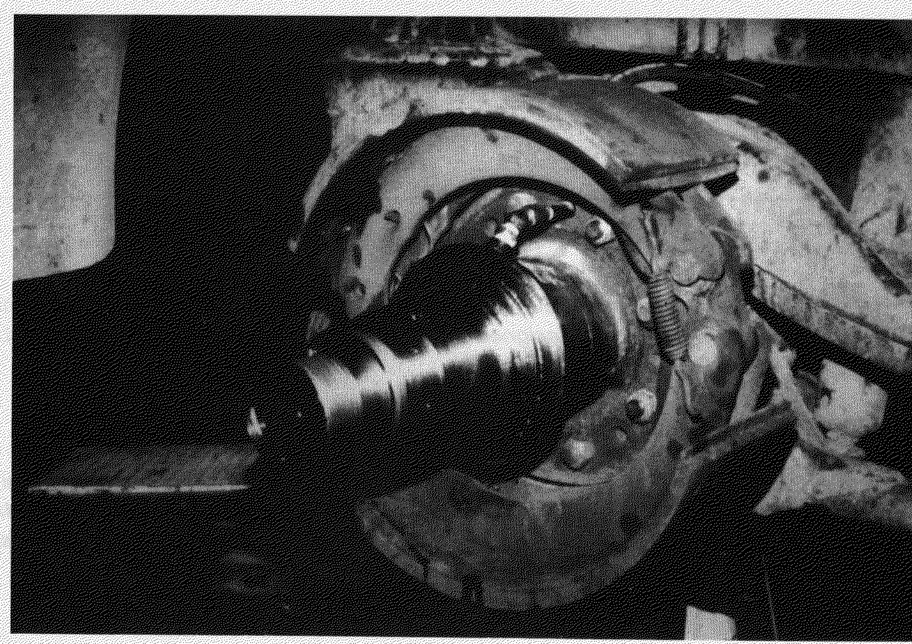

Figure 5.—Eaton CTI drive axle seal.

as Goodyear is concerned. The results of this study were enough to enable Goodyear to make a presentation to the United States Tire and Rim Association (T&RA) recommending that the interim design guidelines which permitted Forest Service experimentation with this technology be made permanent (figure 6).[4] T&RA voted unanimously to accept this recommendation in May 1992.

Design Guide — 2-29-B

Reduced Inflation Pressure Limits for Radial Ply
Tubeless Truck Tires Used Off Highway at Reduced Speeds
(Maximum Speed 35 MPH)

Minimum Cold Inflation Pressures (PSI) at Various Loads (LBS)

Tire Size Designation	*2000*	*2100*	*2200*	*2300*	*2400*	*2500*	*2600*	*2700*	*2800*	*2900*	*3000*
11R22.5	25	25	25	25	25	25	26	28	29	31	32
11R24.5	25	25	25	25	25	25	25	26	27	28	30
	3100	*3200*	*3300*	*3400*	*3500*	*3600*	*3700*	*3800*	*3900*	*4000*	*4100*
11R22.5	34	36	37	39	41	42	44	46	48	50	52
11R24.5	31	32	34	35	37	39	40	42	43	45	47
	4200	*4300*	*4400*	*4500*	*4600*	*4700*	*4800*	*4900*	*5000*	*5100*	*5200*
11R22.5	54	56	58	60	62	64	66	68	71	73	75
11R24.5	49	50	52	54	56	58	60	62	64	66	68
	5300	*5400*	*5500*	*5600*	*5700*	*5800*	*5900*	*6000*	*6100*	*6200*	*6300*
11R22.5	77	80	82	85	87	90	92	94	97	100	102
11R24.5	70	72	74	76	79	81	83	85	88	90	92

Notes:

1. *Reduced inflation pressures applicable for use off highway with vehicles having central tire inflation systems. These CTI systems are to be designed so that normal tire pressure buildup is maintained and pressure is controlled within 3 psi.*
2. *The minimum inflation pressure is 25 psi.*
3. *Prior to entering the local highway system, tires must be properly inflated for normal highway service. Refer to T&RA tables TT-2 and TTB-2 for maximum load limits for these sizes. Since these tables define appropriate "cold" pressures, additional pressure will be necessary to correct for "hot" conditions.*
4. *Reference C1 formula (radial) with* $(P-5)^{585}$*, K=1.25.*

7/21/87
4/20/89
4/9/91

Figure 6.—Reduced inflation pressure limits.

Perhaps the final step needed to enable the private sector to fully absorb CTI systems into the mainstream of truck usage is the establishment of some sort of national standards. A Society of Automotive Engineers (SAE) subcommittee has been established to address this problem, but, because this group is newly formed, it is too early to report on any progress made. We hope that they will work toward common understanding of nomenclature and a framework for a standard performance specification. This subcommittee is a part of the Truck and Bus Council within SAE. The Forest Service has a representative on this body, but the primary push will have to come from industry.

In summary, the development of a reliable CTI system appears to be well on its way. Testing by Eaton Corporation, private logging firms (such as Weyerhaeuser), and the Forest Service points to significant benefits if the system can be counted on to perform well.

Economics

Major successes have been achieved in the system development area. Now the emphasis for the CTI program is to try and describe quantitatively the benefits and true costs of CTI usage. There have been several major efforts made in pursuit of this goal, but more definitive answers are coveted. How much road construction surfacing thickness is actually saved? How much road maintenance can be avoided? How much will a system actually cost the trucker? How much can truck maintenance be reduced due to less shock being imparted to the vehicle? Can driver back injuries resulting from operating off road be reduced? What about vehicle mobility and maneuverability? These are all valid questions that need to be addressed by field experience and structured testing.

CTI systems will probably never be employed on all vehicles operating in off-highway situations. There are areas of the Nation where the amount of off-highway hauling is very small and speeds are too high for reduced tire pressure use while hauling a load. The difficulty of quantifying these limits depends on the many variables that can be addressed in a given hauling situation.

Structured tests have been performed in an effort to address several of the main questions surrounding CTI utilization. In 1986, a contract was awarded to the Nevada Automotive Test Center (NATC). The primary objective of this contract was to compare the effects of reduced tire pressure operation with highway tire pressure operation on two 80,000 GVW western-style log trucks. A secondary goal was to make some estimation of the amount of road maintenance related to each vehicle on the test track. The two test vehicles operated on a closed-loop track, with one vehicle being operated at reduced tire pressure in its own lane, and the second identical vehicle being operated at highway tire pressure, also in its own lane.

Some of the conclusions of the study[5] were:

- The reduced tire pressure vehicle experienced one quarter the part failures of the high pressure truck (7 versus 30).
- For the unpaved portions of the test, tire costs associated with treadwear, tire punctures, and sidewall cuts from rocks caught between dual tires would be lower for the reduced pressure truck.
- The reduced pressure vehicle resulted in lower road maintenance costs on the test track.

The promising results of the NATC test led to the design and award of another contract to the U.S. Army Corps of Engineers, Waterways Experiment Station (WES), in Vicksburg, Mississippi. WES maintains a world-renowned geotechnical laboratory and possesses the skills and equipment to conduct a detailed study of the effects of CTI on road surfacing thickness requirements and maintenance. The test track was constructed in 1988 and operated in 1989. The data gathered is still being analyzed.

Again, a closed-loop test course was designed and constructed (figure 7). This test track contained some thicker asphalt sections, which were funded by the Federal Highway Administration, and followed the NATC test procedure in devoting individual lanes to a reduced tire pressure vehicle and a highway tire pressure vehicle (figure 8).

The three requirements for analysis of relevant data are to determine:

- A surfacing thickness design procedure for both aggregate-surfaced and asphalt paved roads utilizing reduced tire pressure;
- A performance/roughness model for both aggregate and paved surfaces; and
- Maintenance requirements for the various surfaces (test sections) examined.

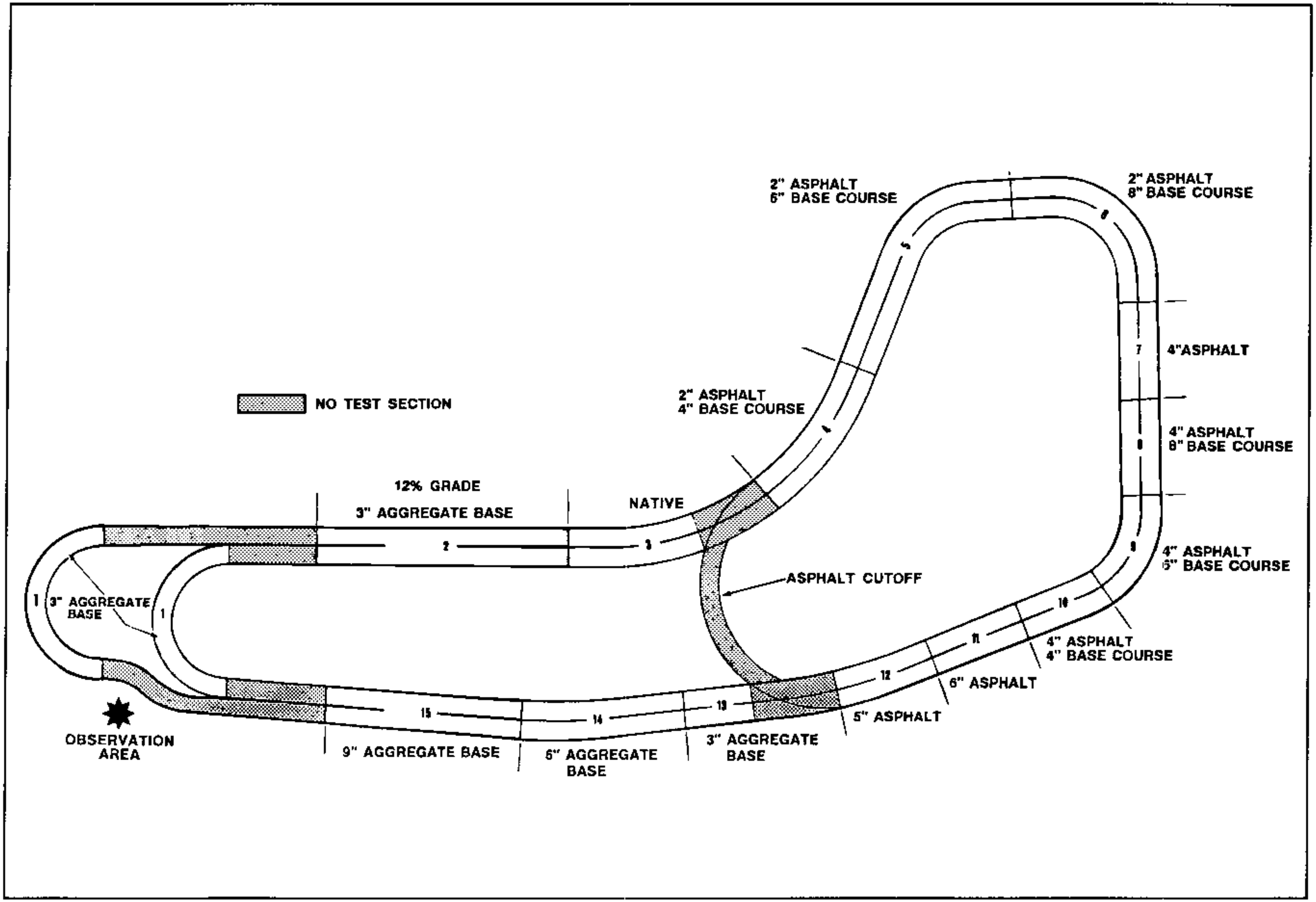

Figure 7.—WES CTI test track, Vicksburg, Mississippi.

Figure 8.—Test vehicles on 12-percent grade, WES test track, Vicksburg, Mississippi.

At this time, WES has completed the analysis of the first item and has developed a rut depth prediction model based on earlier work by Barber, Odom, and Patrick.[6] Their rut depth prediction equation has been modified by information obtained by WES in the 1989 test, and the following formula has been developed, solved for log (*t*):

$$log(t) = (0.3241)\ \frac{P_k^{0.2135}\ t_p^{0.2357}\ R^{0.0719}}{RD^{0.2334}\ C_1^{0.2508}\ C_2^{0.0739}}$$

where,

t = Aggregate Depth (inches)

P_k = Equivalent Single Axle Loads (kips)

t_p = Tire Pressure (psi)

R = Passes of Vehicle

RD = Rut Depth (inches)

C_1 = CBR* of Aggregate Surface

C_2 = CBR of Subgrade

**California Bearing Ratio (AASHTO test T- 192)*

This formula equates to about a 25-percent reduction in surfacing material thickness required to support vehicles operated with CTI tire pressures versus vehicles with highway tire pressures. Many experts feel the WES analysis is conservative because the usable data obtained at the WES test track was from flat grades. This data tends to ignore the destruction of road surfacing on grades that would not be as prominent with a CTI system being employed. This is because the softer tire results in less "tractive hop" taking place on steeper grades.

WES is in the process of developing formulas for base course and asphalt thickness reductions for CTI use. This information should be available by the end of 1992. Additional work continues on maintenance predictions, but the test track did not yield an adequate amount of data to provide a high probability model. Field evaluation will still be needed to address this portion of our economic analysis.

To address this shortfall in our test at WES and to obtain more field confidence in the WES surfacing thickness prediction formula, two tests were proposed. The first test involved a cooperative opportunity with Weyerhaeuser Company in the Pacific Northwest. During early 1992, Weyerhaeuser equipped 10 of their log trucks with Eaton CTI systems in an effort to evaluate them under field conditions.

The Forest Service and the University of Washington School of Civil Engineering recognized an opportunity to cooperate on an actual timber harvest on Weyerhaeuser land. The agreement resulted in the Forest Service providing instrumentation and collecting data, with Weyerhaeuser providing equipment used to install instruments and operating the CTI vehicles in a controlled manner.

For the site involved, a typical aggregate thickness design figure would be about 100 cubic yards per station. Preliminary results indicate that a reduction to 60 cubic yards per station was made possible by operating CTI vehicles over the test sections. The material used was a moderate quality pit-run aggregate. Traffic for this site consisted of about 440 round trips of 18-wheel log trucks with minimal additional light vehicle traffic. Maintenance consisted of spot rock applications for traffic on the highway pressure comparison areas, but no maintenance was required for the CTI reduced tire pressure areas. Severe rutting was noted on the highway pressure sections and almost no rutting on the CTI sections.

The second followup test was conducted by the Forest Service and the Lowell Ranger District of the Willamette National Forest, Oregon. It was conducted during the winter/spring of 1992 in an effort to obtain accelerated road damage during this usually rainy period in the Pacific Northwest. A portion of an existing road system was set aside, and CTI log trucks were operated over aggregate and native test sections. Again, maintenance information was difficult to obtain because there was no control road that was identically constructed for comparison to highway tire pressures, and the number of passes was relatively low. However, the surfacing prediction equations based on the WES test appear to be very accurate.[7] This test will help to instill confidence in our field engineers, because the aggregate material and subgrade was considerably different than that used at the Vicksburg, Mississippi, WES site.

Another area of interest, which may have more bearing on the future of commodity hauling than any other economic variable, is the ability of reduced tire pressure to reduce sedimentation from roads. Sedimentation and road operation may prove to be a major issue when fish habitats are being addressed. Two tests were devised to begin an assessment of this benefit. They were conducted in cooperation with the Forest Service's Intermountain Station research facility located in Moscow, Idaho.

The first test was conducted on the Clearwater National Forest, Idaho, in June 1990. Two test plots were established, one for reduced tire pressure operation and one for highway tire pressures. The plots had simulated rainfall applied in a carefully calculated manner. Sediment yield and concentration was measured and the results tabulated. The highway tire pressure (normal operation) resulted in an average ratio of 1.60 times the yield of the reduced tire pressure runs. Concentration of sediment exhibited a similar increase of 1.71.[8] Inverting these values results in a decrease of sediment production on the order of 40 percent for CTI-equipped vehicles. Of course, this study only represents one data point for one type of soil and operating conditions. Further research is necessary to quantify values for aggregate surfaced roads and varying grades.

An effort was made to continue sedimentation research on actual CTI hauling operations in conjunction with the Weyerhaeuser test (figure 9). Unfortunately, this test relied on natural rainfall, and the unusually dry conditions in the Pacific Northwest during the winter and spring of 1992 resulted in very little information being gained.

Figure 9.—Sedimentation measurement equipment on Weyerhaeuser road near Raymond, Washington.

Conclusions

Work accomplished to date has resulted in the promise of a reliable CTI system adaptable to the trucking industry. We hope that the anticipated market entry of a major corporation will encourage others to get involved, or further involved, in commercial CTI system production. Future Forest Service programs will emphasize determining the economic benefits of CTI— particularly environmental benefits, such as sedimentation reduction—and a better understanding of potential maintenance cost reductions. The results of the WES test track have provided us with an aggregate thickness prediction model for use with CTI vehicles. Further results will, no doubt, provide a model for reductions in asphalt surfacing design.

It is evident that, in order to obtain these cost savings, a substantial number of vehicles need to be equipped with CTI systems. The ability to reduce costs is tied to the acceptability of this new technology. Education and familiarization are required to take this simple concept and make it believable in the workplace. If all the component pieces come together, CTI has the potential to revolutionize the vehicle/road interaction and result in significant savings.

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Icicle Necklace Revetment

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Introduction

An unusual storm struck the Wenatchee National Forest in north-central Washington in November 1990. The storm caused severe damage to many natural and constructed features. The Icicle Road, a two-lane paved facility in the storm's path, was extensively damaged. The nature of the road damage, the sensitivity of the area, and the timing required creative contracting and construction methods. The solution to this difficult problem is presented in this article.

The Storm

November 11, 1990: The Wenatchee National Forest and adjacent lands received a fall rain storm of moderate intensity with isolated areas of high intensity. The soil surface was not frozen, allowing infiltration of water into the soil mantle and partially loading the soil mantle with moisture. This storm was considered a usual fall event, and normal minor adverse effects were experienced.

November 23–26, 1990: The Wenatchee Forest experienced another storm (labeled the "Pineapple Express" by the news media meteorologists), resulting in one of the most significant floods in the Forest's recorded history. The storm combined high precipitation and warm temperatures at high elevations, overloading the already soaked soil mantle with water and filling the water courses far beyond channel capacity. On the forest slopes, the oversaturated soil mantles began to collapse and form debris flows. The stream flows began to cut banks and deepen channels. As the flows encountered roadways, the debris plugged culverts, overflowed the roads, and scoured away roadbeds.

The flowing combination of water, soil, and vegetation produced staggering downstream flooding in the major streams. The flood washed out bridges, bridge approaches, portions of roadways and trails, campground facilities, and archeological sites and caused extensive damage to downstream homes and agricultural lands that lay above the 100-year flood level shown on the Federal Emergency Management Agency (FEMA) river stage maps.

Another storm followed closely on the heels of the flood storm; however, this was a more normal storm with cold December temperatures. A blanket of snow forced the flood assessment workers out of the forest before full inspection of the damage could be accomplished.

The Icicle River Basin

The Icicle River Basin lies between Stevens Pass and Blewett Pass, and the river's headwaters are just south of Stevens Pass. The majority of the basin is a typical U-shaped glacial valley with a meandering stream in a broad flood plain. As the river approaches the mouth of the basin, it flows in a narrow bedrock channel with a steep gradient. The river then empties onto the broad Leavenworth Valley outwash flood plain.

Precipitation Record

Station	Monthly Normal (Inches)	5-Day Precipitation (Inches)	Elevation (Feet)
Blewett Pass	5.3	8.1	4,270
Stevens Pass	13.7	15.3	4,070
Stampede Pass	13.4	13.8	3,860
Dirty Face Mountain	No Record	7.6	5,100

The narrow bedrock section is the site of several severe stream bank erosion areas. As much as 20 feet of horizontal cutting into the stream banks has occurred. A Forest Service trail bridge was washed away, and several sections of the outside shoulder of the Icicle River Road were underwashed and collapsed. This article is about an 80-foot-long site.

The Icicle Road is a two-lane (traffic service level A), asphalt paved, multipurpose facility that ends at the Alpine Lakes Wilderness Boundary. The road is used predominantly by summer recreationists, with year-round use by a small number of upstream private landowners. Within the narrow bedrock section of the river channel, the road was constructed mainly by excavating the rock cliffs. The rock is granodiorite with altered and sheared incompetent zones of significant width.

In the area of concern, an incompetent rock zone runs transverse to the river channel, and previous erosion has resulted in the river making a sharp turn at the downstream boundary where the flow again encounters competent rock (figure 1). The river flow at this turn exerts tremendous energy at the slope directly under the roadway. During the flood, a large portion of the soft rock at the slope toe was scoured away and released the soil and rock under the outer shoulder of the road.

In the spring of 1991, an inspection of the site revealed that the sheared zone also carried ground water. The ground water issued from the face of the failure about 8 feet below the road surface.

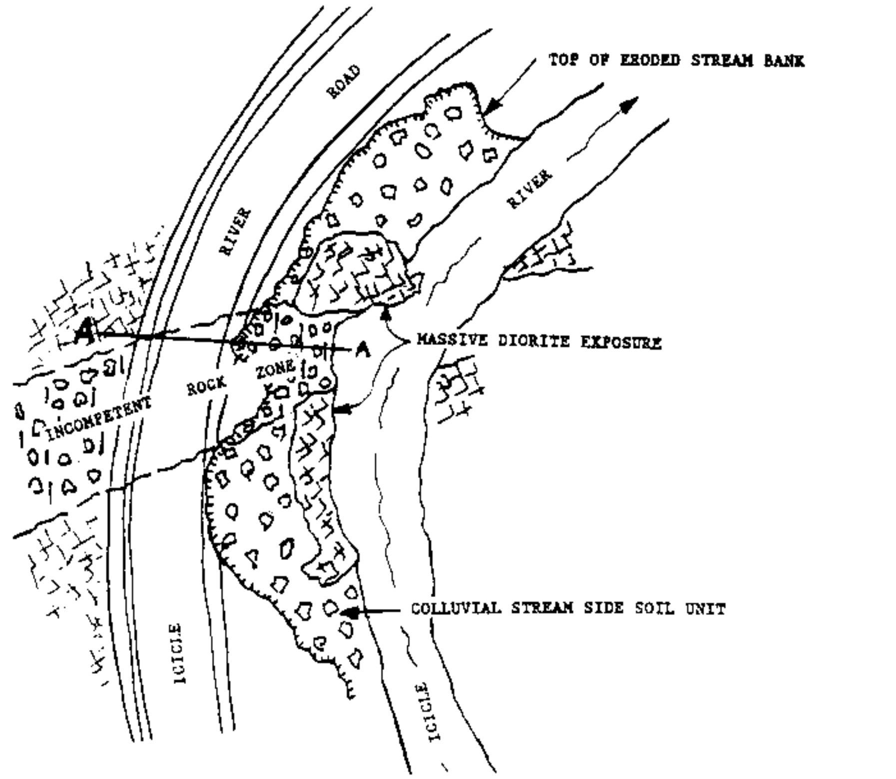

Figure 1.—Plan view sketch—post flood (not to scale).

This river basin is a high visibility area primarily due to public involvement during the planning and implementation of the Alpine Lakes Wilderness. Also, there is a special design review board established by Chelan County that deals with conflicts of use and facility construction on private lands within the drainage. The public is highly vocal concerning planned changes within the drainage.

Requirements and Guidelines

I have listed below a portion of the requirements and guidelines imposed on the repair work.

Wenatchee National Forest Plan

Plans for the repair of the streambank and roadway shoulder must meet the direction and intent of the Wenatchee National Forest Plan.

Wild, Scenic, or Recreation Rivers: This portion of the river is recommended for inclusion in the National System of Wild, Scenic, or Recreational Rivers as recreational.

Visual: Visual Quality Objective: Retention. The desired condition is no change in the visual characteristics of the area. Also, improvement is called for if within the bounds of economics and other technical limitations.

Water: Use the "Best Management Practices" (BMP) document to guide design of all projects. Adjust the BMP to reflect site specific conditions. Conduct management activities in municipal supply watersheds to meet State water quality standards for surface waters. (Icicle River is a municipal watershed for the City of Leavenworth. The intake for the city water system is 0.5 miles downstream of the flood damage site.) Conduct activities to implement the State water quality management plan in accordance with guidance in the Memorandum of Understanding between the Forest Service and the State of Washington.

Facilities: Roads will be designed and constructed as stable and durable structures suitable for their intended use.

Ranger District Traffic Management Requirements

The road must remain open to travel (20-minute delays allowed).

U.S. Department of Interior

The Department of Interior operates the largest fish hatchery in the Northwest along the Icicle River about 4 miles downriver from the flood damage site. This hatchery uses water from this watershed.

State of Washington Department of Wildlife

The Department of Wildlife reviews and closely interacts with the Forest Service designs for protective measures to be utilized during repair of damage along water courses. They voice concerns and provide guidance by issuing a hydraulic project approval document. This document is also reviewed by the Yakima Indian Nation, Department of Ecology, Department of Fisheries, and the Forest Service fisheries biologist.

Hydraulic project approval elements:

- Time Limitations: Project may begin on April 26, 1991, and must be completed by December 31, 1991.
- Hydraulic project approval document will be available on the job site at all times.
- Bank protection work will be confined to damaged banks.
- Watercourse encroachment will be held to a minimum.
- Bank protection material will not appreciably reduce normal watercourse capacity or configuration.
- The toe will be designed to protect the integrity of bank protection material.

- Bank sloping will be accomplished in a manner that will prevent the release of overburden material into the water.
- Bank protection material will be clean, angular rock or other material of a sufficient size to prevent its being washed away by water action.
- Bank protection and filter blanket material will be placed from the bank or a barge. Dumping onto the bank face will be permitted only if the toe is established and the material can be confined to the bank face.
- Alteration or disturbance of the bank and bank vegetation will be held to a minimum.
- Overburden material resulting from this project will be deposited so as not to re-enter the water.

Spring 1991 Field Review

In March 1991, a group of specialists visited the sites to gather information for design prescriptions for the fix. At this and another site downstream, work needed to be conducted at or below the low water level. All agreed that, if possible, the repair work should be accomplished prior to 1991 high water; this was to reduce the risk of further stress to the roadway and damage to the budget.

During this visit, discussion centered on possible sources of riprap. Due to the sensitivity of the drainage, very few sites were available. One excellent source was a side cast waste area from the original road construction. This waste material had been allowed to run downhill and into the river channel. A portion of the flood-stage-wetted perimeter had been filled, causing the flood flow velocities to increase and adding to the river's scouring ability. A proposal to remove the waste material was approved. This mitigated an adverse condition by allowing the future flood stage flows to occupy the natural wetted perimeter and reduce erosive pressure. Also, large boulders, deposited on the Icicle Road at the site of a major debris flow several miles up canyon, were another excellent source. These areas supplied the bulk of riprap needs.

Method of Financing

The Forest applied to the Federal Highway Administration for emergency repair federally owned (ERFO) funds. This site qualified for ERFO funds for repairs to return the road to preflood conditions.

Variety of Repair Plans

Many proposals were made; however, none of them could satisfy all of the stringent requirements of noninterference with the flowing water because they required equipment to occupy space in the wetted perimeter of the stream to accomplish excavation for revetment toe placement. Many also required disturbance of slopes adjacent to the damaged area. This would increase the impact at the site and costs. All proposals included treatment of the ground water.

Selected Method

Because of the limited work area and difficulty with machine access, another method of construction was needed. With the massive granitic ledge rock exposures on both ends of the washout area, it was possible to "tie" the revetment to the massive rock. The work process needed a method that utilized manpower instead of machinery. Rock bolts placed into the massive granitic ledges at both ends of the washout and stainless steel cable tied to the rock bolts provided the "tie."

The next question was how to place riprap rock and have the cable provide intimate contact and restraint to the riprap. Drilled holes through the riprap blocks with the stainless steel cable threaded through the blocks, like a necklace, did the job. Concrete between the blocks and into the annular space between the cable and rocks interlocked the individual pieces into a structure that remained standing at the excessively steep slope required at the site (figure 2).

Specification

It became immediately apparent that there would be a problem with surveying the sites, preparing plans, writing specifications, and assembling a contract for the work in time to effect the repairs needed to prevent further high water site damage.

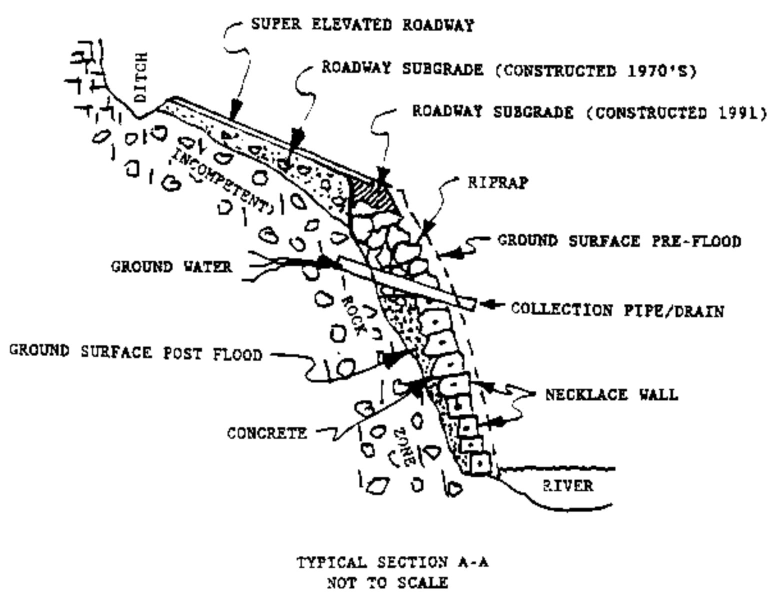

Figure 2.—Typical section A-A (not to scale).

Experienced personnel at the North Technical Center provided the answer by implementation of equipment rental and material procurement contracts. These were carried out under the "Unusual and Compelling Urgency" provisions of the Federal acquisition regulations. The work began in under 30 days. The contracting officer's representative (COR) directed the work of the contractor's equipment and employees. The Government provided the necessary supplies for the contractors' employees to use.

An estimate was prepared of the equipment needs and the number and skills of employees the contractor needed to provide. Estimates and requests for quotes were on a per hour basis. Quantities were actual quantity (AQ). This resulted in the following:

Equipment	*Employees*
60,000-lb excavator with thumb	Operators for each piece of equipment
40,000-lb excavator with thumb	Flagpersons
966 front end loader	Powderman
12-cu-yd dump trucks	Laborers
Bulldozer	
Portable hydraulic rock splitter	
Cat 12-ft motor patrol	
Rock drill with compressor	
Track drill	
Miscellaneous signs for traffic control and security of the work area	

At the same time the contract was being advertised, the Government began securing competitive bids on materials needed for the work. Delivery time was a critical part of the acquisition process. These materials included:

- Perforated drain pipe with couplings
- 3/4-in. stainless steel cable (60,000-lb tensile strength)
- Cable clamps
- 1-1/8 in. diameter by 4-ft-long rock bolts
- Eyebolt with couplings
- Key hole bolt plates
- Grout for bolts
- Grout pump
- Rock bolt setting tools
- Portland Cement concrete
- 1300 lbs of rags
- 1-1/2 to 3/4 in. drain rock

Coordination and implementation of the contract method required the full-time attention of two senior members of the North Technical Center group.

Execution of the Fix

The contract was awarded to Rayfield Brothers Excavation of Leavenworth, Washington. The contractors office and equipment yard are located 4.5 miles from the project so immediate mobilization was possible.

As an alternative to blasting to produce riprap size rock, the contractor suggested using their hydraulic rock splitter. The rock splitter consisted of a compressed-air-to-hydraulic-fluid converter which weighed about 100 lbs and a wedging device on a hydraulic fluid hose, weighing about the same. The splitter, being portable, was the single most effective tool on the project. It split the rock after insertion into an 1-3/4 in. drill hole in the rock. In contrast to blasting, the splitter allows directional breakage, transverse to the wedging pressure, and does not produce conchoidal faces or an excessive amount of spalls (figure 3). Workers did not need to leave the work area during rock breakage. This process produced riprap blocks that fit together very well and eliminated the need to hunt and search through a large pile of riprap and spalls for just the right shape rock to fill a void. Many times the crew made shaped rocks just ahead of placement. The splitting was often done in 5 minutes, including drilling.

While riprap was being produced, the 60,000-lb excavator ramped down in the outside lane of the road to an elevation at which it could reach the toe placement level. The excavator picked up the riprap and swung the block out and down to just the right place. The employees threaded the stainless cable through the block of rock, and, with the excavator lifting slightly, the block was precisely

Figure 3.—Split rock—directional breakage, no fly rock, and no spalls.

Figure 4.—Excavator holds necklace block, crew threads cable.

positioned (figure 4). At the end of the row of necklaced riprap blocks, the cable was threaded through the eyebolt on the end of the rock bolt (figures 5 and 6). Several layers of necklaced riprap were placed and the openings between were packed with 1300 lbs of rags on the face of the revetment.

All rock surfaces were washed to remove dust or dirt and concrete poured and vibrated into place (figure 7). No cement escaped into the water. A top portion of riprap was placed above the necklace wall (figure 8). Horizontal drains were installed behind the revetment to prevent the adverse effects of water.

Summary

Because of the rapidity of preparing the right size riprap blocks—ahead of time and during the placement operation—with the hydraulic rock splitter and the ability to lower and position the blocks precisely, the repair was completed in half the time estimated, and another site was treated in the same manner, all within 30 working days. Within 10 days of completion, the first of the spring rains began and the river stage came up to a point that, had the work not been completed, would have precluded revetment for 3 or more months.

During the work many concerned Agency and private individuals watched and took pictures. Due to the care exercised by the contractor and the ability of the COR to directly supervise the project, no adverse effects occurred.

Figure 5.—Rock bolt installed in massive diorite.

Figure 6.—Diorite exposure—downstream edge of washout stainless steel cable anchored to ledge outcrop.

Figure 7.—Placing concrete.

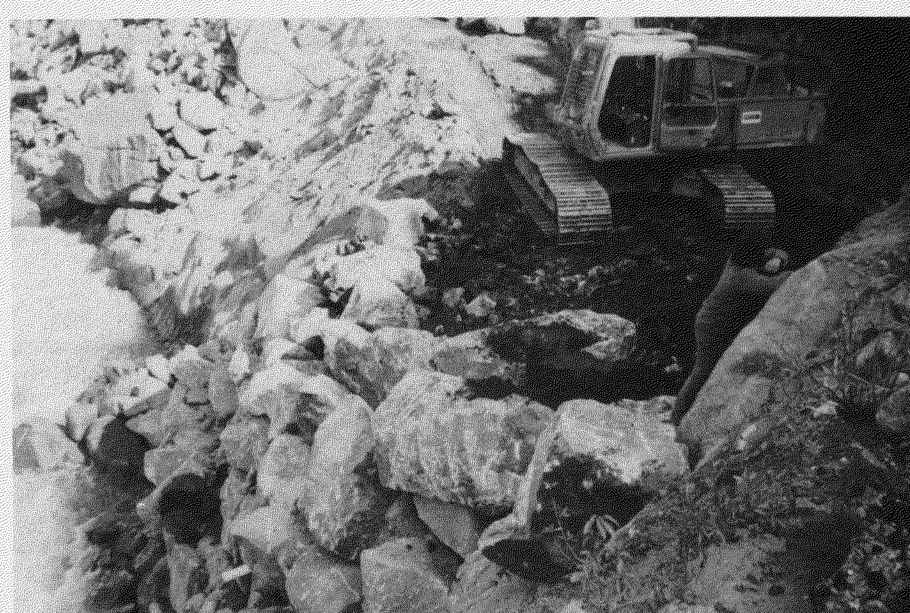

Figure 8.—Placing top portion of riprap above necklace wall.

An Engineering Survey Method for Use With the Laser Technology, Inc., Tree Laser Device

Jeffry Moll

At the present time, the standard survey method widely used by the Forest Service for low-volume and single-use roads includes cloth tape and hand or staff compass traverses, with vertical control and topography information supplied by clinometers or abney levels.[1] Survey measurements are made and manually recorded in a field book at the time of survey, then later keypunched into the data input portion of road design software. Some crews keypunch data into data recorders during the survey for later downloading into a PC. The road may then be designed, slope staked, and constructed.

This article discusses results of a study that used the Laser Technology, Inc. (LTI), tree laser device to update standard road surveying instruments and procedures. The tree laser is basically a handheld total station that makes basic surveying measurements at the pull of a trigger. Data are downloaded and stored in a Husky Hunter data recorder, reducing the need for handwritten field notes, and data keypunching is replaced with electronic downloading of ASCII files into the import portion of LUMBERJACK road design software.

The objective of the study was to project the potential time and cost savings realized by updating surveying and data input activities with the tree laser. Included in the objective were investigating tree laser outputs for the required precision and utility and development of software to facilitate preparation of data files for import into LUMBERJACK road design software.

Use of the tree laser resulted in savings in survey time and cost, in addition to reduced human error during instrument reading, data recording, and keypunching. The instrument person triggers the tree laser, measuring and downloading traverse data to the forward point of intersection (PI), then proceeds to that PI, where the procedure for cross sectioning is executed. The completed survey is a repetition of these procedures for each PI. The road may be designed, slope staked, and constructed as usual. Staking of the location line is required for construction as it is with standard survey methods.

Precision in survey measurements considered acceptable for low-volume and single-use roads are as follows:[2]

- Distances: to the nearest whole foot
- Compass measurements: to the nearest whole degree
- Slope measurements: to the nearest whole percent.

Accuracy of measurements for distance as specified by LTI are plus or minus 0.5 foot.[3] Specifications for the compass are claimed by LTI to be plus or minus 0.5 degree. Azimuth measurements are successfully made only when the tree laser is maintained within a tilt angle of plus or minus 15 degrees (26.8 percent) to the horizontal. Specifications provided by the manufacturer for the tilt sensor are plus or minus 0.1 degree (0.17 percent) throughout a possible measurement range of plus or minus 60 degrees (173 percent) to the horizontal.

The distance measuring capabilities and vertical encoder outputs of the laser device were tested on existing survey monuments in the Corvallis, Oregon, area. Additional temporary benchmarks (TBM's) were established which were conducive to simulating traverse links for a local attraction and azimuth reading error analysis of the compass engine. Test results indicate the distance and vertical angle measuring capabilities of the tree laser are indeed within the manufacturer's specifications and, therefore, meet the requirements of low-volume road surveying. Azimuth measurements from the compass engine, however, do not meet specifications, nor are they precise enough for low-volume road surveys.

A method to correct the local attraction error at an instrument point by using foresights and backsights was employed on survey monuments, but was not successful in isolating the effects of local attraction due to compass calibration problems and other effects.

A standard traverse and cross section survey for low-volume rock creek road 111A was duplicated with the tree laser to provide the basis for a time and cost comparison of standard and tree laser surveying methods. The standard survey was performed by a five-person crew and consists of a 1,631-foot traverse and 38 cross sections. Survey notes were manually recorded in a field book, and wire flags marked with stationing were placed to document the PI's.

The tree laser survey was not expected to match the standard survey data precisely, but was meant to collect the same amount of data and provide similar monumentation of the traverse line on the ground, in other words, to do the same job.

The tree laser survey procedure was as follows: Section number 1 was assigned to the initial cross section at station 0+00 on the centerline of road 111A. The "breaks" on section 1 were each occupied by the rod person with reflector, to allow measurement of vertical inclination (VI) and slope distance (SD) from centerline to each break and the downloading of that information. The breaks were occupied from left to right during data collection. A reading of 0/0 was downloaded into the data recorder to establish centerline location within the stored section data.

At completion of cross section data measurement and downloading, traverse data composed of horizontal vector (HV), a combination of horizontal distance (HD) and azimuth (AZ), and VI ahead to the next PI were measured and downloaded. Section 2, located at the second PI, was then occupied by the tree laser operator, and the cross section data were measured and downloaded, as were data on section 1. The survey of subsequent cross sections and PI's was performed, and the data downloaded in a repetition of the activities described above.

Information concerning breaks on the cross section needed for design purposes, but not visible from the centerline, is collected by use of turning points (TP's). The TP is another break measured to on the cross section, between the PI and the point not visible. LUMBERJACK requires identification of TP's regardless of the survey techniques utilized and automatically considers them in construction of cross section plots.

A time and cost comparison of the standard and tree laser surveys of road 111A was prepared. For purposes of determining crew costs, the General Schedule Pay Scale—January 1992 for Federal employees was applied. The five-person student crew was modeled by using a GS-7 Step 1 party chief supervising four GS-3 Step 1 engineering aides. The two-person tree laser crew was modeled by a party chief and one engineering aide. The wage of the party chief is $10.50 per hour, the engineering aide $6.75. The five-person crew costs $37.50 per hour, or $300.00 per 8-hour day, while the two-person crew costs $17.25 per hour, or $138.00 per day.

The effective working time for a crew is estimated at 5.5 hours per day, because driving, hiking, and break time must be subtracted from the 8-hour work day. The time comparison of the two surveys is provided both in terms of cross sections per day and length of traverse surveyed per day. Each comparison includes the time required to complete all tasks involved with each method. The cost comparison results in dollars per cross section, and dollars per unit length of traverse surveyed.

To provide a comparison of time and cost for surveying and keypunching between survey methods for a road longer than road 111A, the time required to prepare data from an 8,600-foot-long traverse with 200 cross sections for design in LUMBERJACK was extrapolated from the road 111A survey. The ratio of traverse length to number of cross sections is the same for this hypothetical road as it is for road 111A.

Table 1 shows a 20-percent savings in time for the tree laser over the standard survey for a road of moderate length. Production rates, portrayed by cross section or unit length per unit time, show about a 25-percent increase for the tree laser.

Table 1.—Time comparison of standard and tree laser survey methods on rock creek road 111A.

Road Length: 1,631 Feet *38 Cross Sections*	*Five-Person Crew*	*Two-Person Crew*	*Percent Change*
Time (Hours)	3.5	2.8	-20.0
Cross Section/Hour	10.9	13.6	24.8
Cross Section/Day	60.0	74.8	24.7
Feet/Hour	466.0	583.0	25.1
Feet/Day	2,563.0	3,207.0	25.1
Mile/Hour	0.09	0.11	22.2
Mile/Day	0.49	0.61	24.5
Time to Survey 8,600-Foot Traverse With 200 Cross Sections			
(Hours)	18.3	14.7	-19.7
(Days)	3.3	2.7	-18.2

Table 2 shows a 54-percent savings in cost per hour when using the tree laser. Unit costs, portrayed either by dollars per cross section or per unit length, show about a 63-percent decrease for the tree laser method. The total cost to survey road 111A with the tree laser is $48.30, while the standard survey costs $131.25. The total cost to survey the hypothetical 8,600-foot road with the tree laser is $368.00, while the standard cost is $1,000.00.

Table 2.—Cost comparison of standard and tree laser survey methods on rock creek road 111A.

Road Length: 1,631 Feet *38 Cross Sections*	*Five-Person Crew*	*Two-Person Crew*	*Percent Change*
$/Hour	37.50	17.25	-54.0
$/Day	300.00	138.00	-54.0
$/Cross Section	5.00	1.84	-63.2
$/Foot	0.12	0.04	-66.7
$/Mile	600.00	226.00	-62.3
Total Cost ($)	131.25	48.30	-63.2
Cost ($) to Survey 8,600-Foot Traverse With 200 Cross Sections	1,000.00	368.00	-63.2

The actual time required to keypunch the standard survey data into LUMBERJACK's data entry program and check the keypunch job was recorded, as were the times required to bring up the program software on the PC, prepare project files, and reduce and save the data[4] (table 3). These times, rounded to the nearest whole minute, are as follows:

Table 3.—Time required to keypunch standard survey method data.

Task	*Time (Minutes)*
Turn on PC and initialize LUMBERJACK	5
Prepare data files	1
Keypunch and check data	76
Reduce and save data	1
Total	83

The actual time required to transfer data from the tree laser survey in the Husky Hunter data recorder to the PC using HuCOM is shown in table 4. Time for running ROADCONV to modify and format the data and import it into LUMBERJACK, in which it is reduced and saved, are also shown. HuCOM and ROADCONV are described later in this article. The times were rounded to the nearest whole minute as follows:

Table 4.—Time required to keypunch tree laser survey method data.

Task	*Time (Minutes)*
Turn on PC, initialize HuCOM, and transfer data files	5
Initialize ROADCONV to modify and format data	5
Import formatted data into LUMBERJACK; reduce and save data	5
Total	15

The total time in table 3 will vary according to traverse length and number of cross sections. The total time in table 4, however, will vary by only a few seconds with different length surveys; thus, it can be considered a fixed quantity.

The extrapolated total time for the hypothetical 8,600-foot-long road is as shown in table 5.

Table 5.—Time required to keypunch standard survey method data for 8,600-foot traverse with 200 cross sections.

Task	*Time (Minutes)*
Turn on PC and initialize LUMBERJACK	5
Prepare data files	1
Keypunch and check data	400
Reduce and save data	1
Total	407

As can be seen by inspection of tables 6 and 7, the savings in keypunch costs for the tree laser over the standard method reaches phenomenal proportions as the length of road surveyed increases.

Table 6.—Cost comparison of standard and tree laser data keypunching for rock creek road 111A.

Road Length: 1,631 Feet 38 Cross Sections	*Five-Person Crew*	*Two-Person Crew*	*Percent Change*
$/Cross Section	0.38	0.07	-81.6
$/Foot	0.01	0.0016	-84.0
$/Mile	47.02	8.50	-81.9

Table 7.—Cost comparison of standard and tree laser data keypunching for hypothetical 8,600-foot traverse with 200 cross sections.

Road Length: 1,631 Feet 38 Cross Sections	*Five-Person Crew*	*Two-Person Crew*	*Percent Change*
$/Cross Section	0.36	0.013	-96.4
$/Foot	0.01	0.0003	-97.0
$/Mile	43.73	1.61	-96.3

The HuCOM Batch File Transfer Utility

The HuCOM batch file transfer utility software, enabling the transfer of files between a Husky Hunter 16 and the PC, in addition to technical support and training in software and Hunter 16 usage, is available from: Northwest Signal Supply, Inc., 17410 SW. 63 Avenue, Lake Oswego, OR 97035. Phone: (503) 635-4351.

The ROADCONV Program

A program, named ROADCONV, was written specifically for this study in Turbo Pascal program language to prepare tree laser data previously downloaded to the PC for import into the LUMBERJACK road design program. The required format for ASCII files to be imported is furnished in the LUMBERJACK program documentation. Tasks required of the program include:

(1) Stripping the actual measurements from the tree laser output record, which is comma delineated and complies with the NMEA-0183 standard for record structures.[5]

(2) Identification of data type, for example, HV. HV exists in the data output string as an identifier. The other identifiers are HD for horizontal distance, SD for slope distance, AZ for azimuth, and VI for vertical inclination.

(3) Conversion of vertical encoder output, which is identified by VI, from units of degree of slope to percent slope units of feet per 100 feet.

(4) Cataloging of the stripped data into the specific format required by the LUMBERJACK program. LUMBERJACK software contains provision for the import of specially prepared ASCII files.[6] A sequential section number must precede each set of traverse and cross section data strings. A "777" code must be entered at the end of data entry for each section.

The program thus prepared is very basic and intended to serve the function of preparing the road 111A survey data for import into LUMBERJACK as a basis for the time and cost study. Elegance and user friendliness of the program were not priorities in software development.

The LUMBERJACK Program

The LUMBERJACK road design system is suited to low-volume road design and has ASCII file import capabilities. The required format for imported files is supplied in the program documentation. The software, along with program documentation and technical support, is available from: Alternatech, Route 1, Box 492A, Bonners Ferry, ID 83805. Phone: (208) 267-7745.

Improvements to the Tree Laser and Areas for Further Study

Improvements to the next generation of tree laser include a reduction in the range of variation in slope distance measurements, from plus or minus 0.5 foot to 0.25 foot.[7] Additionally, the minimum distance the laser will successfully measure will be reduced from approximately 15 feet to less than 9 feet. A more reliable compass with an improved gimbal arrangement is being incorporated into the new device. No modifications are proposed for the vertical inclinometer on the tree laser. A yoke for tripod cradling is available from LTI.

Improvements to the Tree Laser and Areas for Further Study

Provision for an increase in data storage volume and manipulation capabilities will be incorporated. Up to 1,350 data sets may be cataloged for up to 20 separate surveys. Each data set consists of the three dimensional information needed to describe a location in space. Also, the provision for side shots, which are used as cross sections, will be made.

Other potential improvements include the storage of instrument and target reflector heights for each data set. This feature will increase the utility of the device and make possible greater improvements in the efficiency of surveying.

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This issue lists material published since our last bibliography (*Engineering Field Notes*, Volume 23, November–December 1991). Copies of *Engineering Field Notes*, *Technology & Development News*, *Engineering Management Series*, and other publications listed herein are available to Forest Service personnel through the Engineering Staff Technical Information Center (TIC). Copies of "Project Reports," "Tech Tips," and "Special & Other Reports" are available from the San Dimas Technology & Development Center.

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Engineering Field Notes

This publication is a bimonthly periodical that supplies the latest technical and administrative engineering information and ideas related to forestry and provides a forum for the exchange of such information among Forest Service personnel.

EFN by Title

MTDC Seedling Counter Field Tests	Gasvoda, Dave and Herzberg, Diane. EFN 24 (September-October 1992): 29-42.
NFAP Light Aircraft Airborne Video System with Real-Time Differential GPS	Alban, Jennifer, Ishikawa, Paul, and Hoppus, Michael. EFN 24 (May-June 1992): 19-23.
Networking Geometronics Style	Vest, K.D. EFN 24 (July-August 1992): 25-30.
Partnerships—A Philosophy	Lay, Clyde. EFN 24 (May-June 1992): 25-29.
Portable Power Platform	Windell, Keith. EFN 24 (January-February, March-April 1992): 23-25.
(A) Summary of Roads Technology and Development Projects	Steward, John E. EFN 24 (May-June 1992): 1-6.
Update on the Soil Nail Launcher Demonstration Project	Steward, John E. EFN 24 (September-October): 23-28.
Why I Did It	Bertrand, Wendy S. EFN 24 (July-August 1992): 31-34.

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Alban, Jennifer, Ishikawa, Paul, and Hoppus, Michael. EFN 24 (May-June 1992): 19-23.	NFAP Light Aircraft Airborne Video System with Real-Time Differential GPS
Bassel, James R. EFN 24 (May-June 1992): 11-17.	Impact Tests on Road Delineator Posts—The Bradystake and Three Carsonite Marder Designs
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Steward, John E. EFN 24 (May-June 1992): 1-6.	(A) Summary of Roads Technology and Development Projects
Steward, John E. EFN 24 (September-October 1992): 1-22.	History of Reinforced Walls in the USDA Forest Service
Steward, John E. EFN 24 (September-October): 23-28.	Update on the Soil Nail Launcher Demonstration Project
Vest, K.D. EFN 24 (July-August 1992): 25-30.	Networking Geometronics Style
Whitmill, Lee and Floor, Phil. EFN 24 (July-August 1992): 35-44.	Joint Global Positioning System-Aerial Triangulation Project Final Project Report
Windell, Keith. EFN 24 (January-February, March-April 1992): 23-25.	Portable Power Platform
Zirkle, John. EFN 24 (January-February, March-April 1992): 31-37.	Being More Effective

Engineering Management Series and Other Publications

The Engineering Management (EM) Series contains publications serving a special purpose or reader and publications involving several disciplines that are applied to a specific problem.

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Working Capital Fund User's Guide	EM-7130-3

Technology & Development News

"Technology & Development News" contains information on specific projects, new ideas, and new technologies being developed by the Technology & Development Centers to help solve many different kinds of resource management problems.

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GPS Update	May-June 1992
GPS Update	September-October 1992
Handtool Sharpening Gauge	March-April 1992

Title	***Issues***
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Laser Cruising Equipment	September-October 1992
More Newly Available SDTDC Reports	January-February 1992
Mountain Bike Trail Guide	September-October 1992
NFPA 1977 Proposed Standards	July-August 1992
Portable Power Platform	January-February 1992
Portable Wetland and Stream Crossing	March-April 1992
Recent MTDC Publications	July-August 1992
Recent Publications of Interest	July-August 1992
Report of FS Wilderness Aircraft Overflight Sound (WACOS) Study Sent to Congress	September-October 1992
Revising the Forest Service Health and Safety Code Handbook	March-April 1992
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Smallwood Survey Results	January-February 1992
Temporary Signs	May-June 1992
Three Newly Available Publications	September-October 1992
Visual Prioritization Process (VPP)	March-April 1992

Tech Tips

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Title	Source*	Number	Date
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New—Traditional Style Single Unit Accessible Toilet	SDTDC	9223 1302	5/92
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Project Reports

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Field Survey of Helicopter External Accessories & Review of Inadvertent External Load Releases	SDTDC	9257 1202	7/92
Field Survey of Helicopter Foam Injection Systems	SDTDC	9257 1201	6/92
Proportioners for Use in Wildland Fire Applications	SDTDC	9251 1204	9/92
Utility Hookups for Campgrounds	SDTDC	9123 1209	11/91

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Special & Other Reports

Project Reports are detailed engineering reports that generally include procedures, techniques, systems of measurement, results, analyses, special circumstances, conclusions, and recommendations rationale.

Title	Source*	Number	Date
Fire Equipment Storage and Refurbishing Standards	SDTDC/ BIFC	NFES 2249**	7/92
Foam Applications for Wildland & Urban Fire Management	SDTDC	Vol. 4, No. 2	1992
Foam Vs. Fire, Class A Foam for Wildland Fires	SDTDC/ BIFC	NFES 2246**	6/92
Foam Vs. Fire, Primer	SDTDC/ BIFC	NFES TBA**	10/92
In–Depth Design and Maintenance Manual for...Vault Toilets...	SDTDC	9123 1601	7/91
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Smallwood Equipment Catalog	SDTDC	9224 1501	3/92
Smallwood Survey Results	SDTDC	9124 1805	9/91
Spark Arrester Guide, General Purpose and Locomotive	SDTDC/ BIFC	NFES 1363**	5/92
Spark Arrester Guide, Multiposition Small Engine	SDTDC/ BIFC	NFES 2363**	5/92

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***National Fire Equipment System (NFES) publications must be purchased from the Boise Interagency Fire Center (BIFC), BLM Warehouse Supply; 3905 Vista Avenue, Boise, ID 83705.*

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