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Field Notes

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ENGINEERING FIELD NOTES

This publication is a monthly newsletter published to exchange Engineering information and ideas among Forest Service personnel.

The publication is not intended to be exclusive for engineers. However, because of the type of material in the publication, all engineers and engineering technicians should read each monthly issue.

The publication is distributed from the Washington Office directly to all Forest, Regional, Center, Station, Area, Laboratory, and Research Offices. Adequate copies are printed to provide all who wish a personal copy. If you are not now receiving a personal copy and would like one, ask your Office Manager or the Regional Information Coordinator to increase the number of copies sent to your office. Use form 7100-60 for this purpose. Copies of back issues are also available from the Washington Office and can be ordered on form 7100-60.

It is intended that the material in the Field Notes be primarily written and used by Forest Service Field Engineers; however, material from other publications may be used.

Field Note material should always be informative and cannot contain mandatory instructions or policy. The length of an article may vary from several sentences to several typewritten pages. Material need not be typed (neatly written or printed is acceptable), or edited before being submitted to the Washington Office. This will be done in the Washington Office to accommodate our format and allowable space.

Each Region has an Information Coordinator to whom field personnel should submit both questions and material for publication. The Coordinators are:

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R-5	Chuck Paletti	WO	

PEOPLE AND ENVIRONMENT [1/]

by R. D'Arcy Bonnet

Books have been written, motion pictures have been produced, and magazine articles have been published extolling "America the Beautiful" and beautiful it is. That is good, we like to know that the America we have not yet seen is beautiful. In 1963, Sunset Magazine published a book titled, "Beautiful California." This is a book of real quality, the paper is the finest, the binding excellent, the text is informative, and the photography is the work of some of the most skillful artists in the west. Thousands of copies have been sold and people praise it highly. On the jacket of the book, there is this statement: "Here for the first time is the complete picture of California, presenting in outstanding photographs the many varied faces of the State."

In truth, however, one face is missing -- that is the face of California where we live, work, sleep, play, and breathe. This face of California, like the same face throughout the rest of beautiful America, is in a horrible mess. This face is "Ugly California" and it grows more ugly at a rate faster than efforts of concerned citizens can control it.

A few days ago, I received the monthly news letter from the congressman of the 12th District of California. In the letter he quoted from a statement on environment by a very well known American who, incidentally, had a great interest in the National Forests. The quotation is as follows: "Here in the United States, we turn our rivers and streams into sewers and dumping grounds, we pollute the air, we destroy the forests and exterminate the fishes, birds, and mammals -- not to speak of vulgarizing charming landscape with hideous advertising. But, at least it looks as though our people are awakening. Many leading men, Americans and Canadians, are doing all they can for the conservation movement."

That sounds like it might have been given by some candidate for public office last week. No, it was part of an essay by Theodore Roosevelt in the Outlook Magazine of January 25, 1913. It is hard to believe that in 58 years our advanced technology and affluence has done nothing to correct these conditions, only to extend them and make them worse. Something must jolt us out of our lackadaisical approach to our environmental problems. In the good old days, there seemed to be such an

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1/ Excerpts of a paper presented by R. D'Arcy Bonnet, Retired Chief Landscape Architect, Division of Recreation, R-5, at Environmental Workshop for Engineered Facilities at Marana, Arizona, April 22, 1971.

abundance of resources that a little waste did not matter -- or so it seemed. Today, that little waste has grown to include millions of acres of prime agricultural lands to tract home builders and freeways; ugly litter; endless billboards; overhead wires; honkytonk commercialism along the highways; poisons and sewage in our rivers, lakes, and oceans, and choking smog in our cities. All of this ugliness is the result of man's capacity to befoul and destroy in the absence of policy, planning, and controls.

There is a good side to the mess in our cities and countryside, however. It seems that we Americans never get excited about anything until it becomes so outrageous that everyone demands a change. It has almost reached that point with the environment. The destruction of the environment and pollution is so widespread throughout the land that many people have become outraged. It is too bad that we have to lose so much before we learn the lesson. But people are being heard -- most of the new land use legislation and pioneering programs to halt destruction and pollution did not come about as the result of foresight and careful analysis. They were passed by the Congress and State Legislatures because people got mad over the things they could see with their own eyes. Some of the most significant legislation in local communities can be traced to a comparatively small local outrage such as a row of trees being chopped down for a road widening project, or the enclosing of a river in a concrete ditch for flood control. The quality of the environment has become a "Gut" issue and politicians have been sensing it well. The result has been a number of laws which broaden the public's control power over land uses and environment. You are familiar with most of them and I am sure that you have used their powers frequently. The National Environmental Policy Act is the greatest, and then there is the Highway Beautification Act and State laws on scenic highways, and Air and Water Pollution Control Acts. Any one of these laws would have seemed wildly socialistic a decade ago, yet they were passed with suprisingly little controversy.

These laws establish the broad policy and operate at the higher levels of Government. In local areas, people are giving considerable attention to what they can do. Many are beginning to question the value of gaining more population, more freeways, and more goods if these are obtained only at the expense of clean air, pure water, songbirds, uncluttered skylines, shaded streets, unspoiled landscapes, and even our health. Every day newspapers, radio, and television present information relating to the environment. High schools, colleges, and universities are teaching courses in ecology and environment. Students are electing these above all others. An encouraging sign in the part of the State where I reside, students appear and speak at planning commission, city council, and county boards of supervisor's meetings when items on the agenda involve environment. The younger generation is getting angry, and that is favorable.

A news article in last week's paper quoted Ralph Nader's recent report on water pollution in the nation's rivers and lakes. The report states that industrial polluters and Government have combined to turn rivers and lakes into a water wasteland. Not only sewage, but also hundreds of sophisticated chemicals are dumped each year. On the basis of his research, existing laws are so inadequate that industry can secure a virtual license to pollute through "political sabotage." Nader's report urges some drastic reforms in the enforcement of the pollution laws. These are:

1. Pollution control officials are not to be permitted discretion to decide whether they will or will not enforce pollution laws against industry violators.

2. Public officials who are found to have knowingly acquiesced in pollution be subject to the same penalties as those who caused pollution.

3. Individual citizens be given the right to sue industrial polluters who fail to meet Federal and State standards.

Another interesting news item came out of Oakland, California, a few days ago. The article quoted Fortney Clark, president of the Security National Bank, who addressed the California Environmental Health Association as follows: "If it's a crime to pollute, whom do you charge? Maybe we should charge those in command. They are responsible for it. Felony pollution -- that would be an interesting sort of charge, especially with penalties up to five years in prison. Throw a few chairmen of the board in jail for polluting the air and water, and you will see pollution disappear quite rapidly. Top corporate officers consider themselves the ultimate of good citizens in private life, but as long as their companies continue to poison the environment, they would just as well be classified as criminals. Business is the negative force in defeating ecology laws 99 percent of the time, mainly through lobbying and public relations activities." I do not know Mr. Clark, but he makes very good points if we are ever going to stop pollution and other destructive practices, and conform to the intent of the laws.

It is going to be difficult -- for those who make money in the process of polluting and destroying our natural resources and environment possess awesome political power. However, people have the power to halt the spread of blight and return this beautiful land to the splendor it once was.

Today we have the constitutional right, the technical know-how, and the money. All we need to do is to establish objectives and organize to fight. It will not be easy -- the opposition is formidable. Within the constraints of law, they are ruthless. Anyone who has had to contest

the loggers, highway builders, or the electric power producers will certainly have deep scars. William Bronson, editor of the publication, "Cry California," a magazine dedicated to the fight to save the environment, believes that this era we live in may be remembered in history as the Age of Paid Liars. "American business and government are full of honorable men; but when it comes to protecting their own, be it the right to destroy the last redwoods, or muck up the waters, smog up the air, cover the cities and roadsides with billboards, ram a freeway through a park, construct power and telephone lines in front of a beautiful church, build an instant slum, dam the last wild rivers, they are known to use political power and outright deceit as freely as if it were sanctioned by Heaven."

There is no question that the issues of environment protection are big and complex -- the opponents are strong both politically and financially. It will take the best brains and intestinal fortitude for the people to win. People are winning a few little battles in the local communities. I will tell you of some victories which have been won in the area of California in which I now reside. This is Watsonville, in Santa Cruz County, on Monterey Bay, about 100 miles down the coast from San Francisco, with a population of 15,000. We had air pollution. Fortunately, we are so situated that we have very little of the common smog problem, because we seem to have a built-in natural air conditioning system generated by the Pacific Ocean and operated by the Good Lord. Two years ago, Pacific Gas and Electric Company built a very large electric power generating plant a few miles out of town. On the first day of operation, a great dense cloud of dirty yellow colored smoke belched out of the tall stacks and drifted across the clear blue sky of the Pajaro Valley. People were shocked, and pleaded with the company to do something to correct this. P.G. & E., as expected, did nothing; but the Pulitzer Prize winning local newspaper was aroused to action, and printed editorials and news articles. The City Council and the County Board of Supervisors then demanded P.G. & E. make some modification in operation, which would reduce the volume of smoke over the Valley. The company recognized these authorities and did reduce the volume to about 20 percent of what it was in the beginning, and they are able to reduce it even further if the people think it is necessary.

We have water pollution in Monterey Bay, caused by the discharge of secondary treated sewage into the Bay from the cities along the shores. Those who support this method of disposal say facetiously that "dilution is the solution for pollution." Moss Landing Sea Grant Laboratory biologists' studies show that there is almost no current in the Bay, and sewage dumped into it remains in the Bay. They further report that substantial changes are occurring in the underwater environment from the pollution. Signs are posted on the beaches every year by the County Health Officials, stating the water is polluted and unfit for swimming. Most of the cities have new plans

for the further treatment or disposal on land, so that the purity of the water in the Bay may be regained in the near future. A potential hazard of great magnitude is that San Francisco is planning to transport its sewage to the ocean just north of Monterey Bay. I need not tell you how the people along the Bay feel about this threat. So we will have to be alert.

Freeways have been wonderful inventions for getting people from one place to another rapidly; but they do have a way of upsetting desirable land use patterns. Santa Cruz citizens believe their environment is well worth preserving, and that freeways will be a threat to it, by making it possible for a very large increase in population to live here and work in the crowded urban San Francisco-San Jose complex. Recently the people of the County have requested the State to remove the two proposed freeways in the County from the State freeway plan.

Monterey Bay shoreline is bordered for most of its length by a steep bluff about 100 feet high. Several large apartment complexes have been built, hanging on the slope of the bluff. These apartments provide spectacular living for those people who have been able to purchase them; but they certainly are destructive of the beautiful environment of the extensive sandy beaches. County zoning ordinances prohibit these kinds of housing developments in the future.

Santa Cruz Mountains, just a few miles from the ocean shores, are the southern-most commercial redwood timber growing area. This part of the State contains a few remnants of the old growth which once covered large sections. Logging of these remnants are following the same destructive practices as that in Northwestern California, with the same destructive results. Last winter a normal storm washed down logging debris and flooded over quite a few residential properties. State logging standards are entirely inadequate to protect Santa Cruz property from damage. Ordinances have been passed by the County which drastically limit logging in the interest of protecting property and the environment. Everyone seems happy except the loggers.

Recently an application was made to the County Planning Commission for a residential subdivision outside the city on very steep forested land in Corralitos Creek Canyon. This proposal was located about one-quarter mile above the Watsonville water supply intake, and of course the city objected strongly. At the public hearing before the Planning Commission, the real opposition to the subdivision came from a group of college students who appeared before the Commission to plead for preservation and protection of the environment in Corralitos Canyon. They were successful, and it was my pleasure to have given the leader of the group some of the basic arguments against the proposal even to the hazards from wildlife in such an area.

Not all dangers to the environment come from greedy entrepreneurs. Some are created by single purpose projects of Government. Sixteen years ago, Pajaro River, which runs along one side of Watsonville, flooded over its banks upstream from the end of the levees. The rich farmland and the city, which are protected by the levees, had some flood water. There was very little damage because the valley is flat. It was muddy and inconvenient for a few days. The Army Corps of Engineers, under whose supervision the original levees were built, make a comprehensive study of flood control for the Pajaro Valley. The flood control plan and project calls for a concrete rip-rap channel from just above the city to the mouth of the river, a distance of about 4 miles.

Two years ago, when the plan was presented to the local governments, Monterey and Santa Cruz Counties and the city of Watsonville, there was a great clamor by the public. They foresaw that the concrete ditch would flush all the fresh water to the ocean rapidly. The wells that irrigate six crops a year of lettuce and celery would surely begin to supply only salt water, as there would no longer be a fresh water supply to replenish the underground water table.

The people of the city of Watsonville have never treated the bank of the Pajaro River as a valuable resource, but when confronted with a potential concrete lined ditch about 200 feet wide through the city to the ocean, they balked and balked loudly. A committee of interested citizens representing the two counties and the city were appointed officially to study the proposal and make a report. During the past 1 1/2 years, I have had the pleasure of serving as a consultant for recreation and esthetic problems which may be created by the proposed flood control project. Conclusions so far are that the Committee must study the entire Pajaro watershed, its resources and its problems, and prepare a comprehensive plan for flood control and resource conservation for the entire basin. We have invited Santa Clara and San Benito Counties to join with us, for they include the greatest area of the watershed.

Leon Thomas formally of R-5, R-8 and WO is a representative from Santa Clara County. Santa Clara County Flood Control District officials are already studying a proposed upstream reservoir which is estimated to take 10 percent off the peak of any foreseeable flood in the lower part of the river. This stored water would be used for irrigation, domestic use if needed, stream flow maintenance, and holding back salt water intrusion from the water table. In accord with the National Environmental Policy Act, the Committee prepared an environmental report on the proposed project. This report is a classic. We really need a good definition of environment.

The Committee's environment report makes the point that flood control prevention, as they projected it, will create an environment which would relieve the troubled minds of the people living under the threat of a potential flood. They included several pages of wild birds and animals found in riverside locations and in summary stated most of the vegetation along the river would be removed for maximum flood control!

Next Monday night we shall have members of the San Francisco District of the Committee who have authority to discuss the entire problem. It should be a real warm meeting.

I am certain that similar local problems of environment are occurring all over the nation, and my hope is that local people are becoming vigilant and, yes, vociferous in their efforts to control destruction.

The National Forests are the lands with the best opportunity in the entire nation to show that the lands can be used and yet preserve the environment for the people now and future generations. National and State parks are only preserved lands, private lands for the most part are only used for profit. The objective of our management must carry with it the protection of the environment first, even before the economic resources are programed for use. If National Forest management cannot successfully protect the environment, no management can succeed because these are national lands -- they were not established for profit. They were established to be managed for the greatest good of the greatest number in the long run -- that does not say the greatest good is the largest money income to the Treasury or to American business -- it certainly includes those social and intangible values as watershed, scenery, and the like.

Recent laws particularly the National Environmental Policy Act and more recent Executive Orders clearly emphasize the importance of enhancing and protecting our environment on federal lands for today and the future.

It is indeed encouraging to see how fervently the Service is working to develop procedures for accomplishing the objectives of the law and policies. What wonderful challenges you have today -- when we had engineer training meetings in the past, we talked of getting roads built as fast and cheap as possible. We know now how foolish some of our policies were, because we destroyed or polluted greater values than the cost of the roads. I am a firm believer in the team approach which allows collaboration of people from all the interested professsions to design improvements which will be constructed on National Forest land. I am sure by this approach, you will build projects that will serve their intended function and at the same time will meet acceptable environmental standards.

Now I have a few suggestions which may help us on the way to better environment:

First, "LET'S STICK OUR NECKS OUT" for environment. You have heard much criticism of the Forest Service, and you will hear more as time goes on. You have asked yourselves "What has gone wrong? Why do we get so much adverse criticism?" One of our troubles is that we no longer want to be out in front -- sticking our necks our nationally in defense of the non-economic, social, and intangible values. We do

not speak out loud and clear that we believe in protecting intangible values at all costs! No, we draw back and say that we believe in the principle that economic values must not be locked up and prohibited from use. In California, we held up approval of an important wild river for several years because one man in power was against the principle of designating areas to that use. Let me trace back into history and tell you of times when the Forest Service did stick its neck out. Do you know that the Forest Service between 1928 and 1932 established the first wilderness type areas and those 50 or 60 areas known as Primitive Areas then now form the basic Wilderness System.

What agency of the Government first adopted the policy of preserving scenic strips along all highways? It was the Forest Service at the time the first Federal Highway Act was passed -- 1918, I think. We Landscape Architects think that we are a new professional group in the National Forests, but Professor Frank Waugh of the Landscape School, Massachusetts Agricultural College was employed in 1916 to advise the Service on landscape and scenic problems!

What agency bravely informed the nation of the wasteful conditions occurring on private timberlands throughout the country, and threatened to urge Congress for Federal controls if the States did enforce misuse of the timber resources. Most of the States did enact forest practice laws. In the 1930's, the Forest Service told this true story despite the threats and intimidation by the lumber industry. The Wild Rivers program of recent years was given enthusiastic support by the Forest Service. The Forest Service stuck its neck out back in 1947, when we demanded the Federal Power Commission include a stipulation in a new power project license which would insure an acceptable flow of water in the Kern River during the full year. Our arguments were based upon the potential value for public recreation. This was the first attempt that had been made to include public recreation in power developments. Since that time, requirements have been expanded in scope, and now the F.P.C. requires the applicants for license to submit a report on recreation values and what the applicants intend to do in the way of providing for future public needs.

All of these historical actions came about through necessity to redeem our responsibility to the people of the United States. Now we have the new National Environmental Policy Act which says these same things, and gives us the law to make certain we do. It is right in the Forest Service ballpark. National Forest Management deals with environment at all times. I urge you to get on with broad programs of environmental protection, put them into action on the National Forests, and go preach it nationwide.

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SKI LIFT THRUSTOR BRAKE PROBLEM

By Charles G. Bovey,
Engineer, Caribou N. F., R-4

The General Electric thrustor brake, as used on modern ski lifts, is normally a relatively trouble free and rugged unit. However, problems do occur with these brakes from time to time. This article deals with one of these problems.

This particular lift was constructed in 1967 at the Skyline Ski Area, 17 miles southeast of Pocatello, Idaho. It is a Miner-Denver double chair lift, 4,524 feet long, with a 1,642-foot rise, and a capacity of 700 people per hour.

On the night of February 22, 1970, the control building for the lift was destroyed by fire. The lift itself was damaged extensively, but the combined tension and drive unit (Iron Horse) was undamaged. Major damage occurred to the cable. The core melted and flowed out of about 50 feet of the cable, and another 200 feet was considered unsafe. The counterweight moved approximately 18 inches from the unloaded position, indicating that the damaged cable stretched approximately 36 inches. Due to the close proximity of the existing cable splice, we replaced about 700 feet of cable which required only two splices in the cable, rather than three splices if only 250 feet of cable had been replaced.

Upon completion of the repairs the lift was load tested. At 50 per cent load (25 chairs) the lift was stopped, and the backstop tested by forcing the thrustor brake off with a 2x4. Both backstop and thrustor brake appeared to be working. When the uphill test was completed, the downhill test commenced. This test consisted of leaving every fourth chair loaded, with two consecutively loaded chairs approximately in the center. As the test progressed and the number of downhill loads increased, it became more and more difficult to stop the lift. The thrustor brake had been examined prior to the test and appeared to be working satisfactorily so we thought that it was merely out of adjustment. We tried unsuccessfully to adjust it and the operator said he would have his maintenance man adjust it the next day. With the concurrence of the operator, the load test was completed using the hand brake on the bull wheel.

The method used to check the brake was to open the inspection door of the Iron Horse to see if the operating rods were moving and if all parts were free. At the same time, the movement of the lift was observed to see that the lift was stopping smoothly with no roll back.

Three days after the load test, the brake was retested at the request of the operator. On the first trial it appeared to work. On the second trial it did not. Again an attempt was made to adjust the brake. After this attempt, the pushrods would not move and could not be released, even with a pry bar.

The operator dismantled the unit and took it to the General Electric Shop in Salt Lake City. Their diagnosis was that the wrong oil had been used in the unit. The oil had congealed to the consistency of mayonnaise. Since this unit consists of a piston moved by hydraulic pressure, generated by a small turbine pump, changes in viscosity of the fluid can drastically affect its operation. The plans and specifications for the lift did not specify any particular type of oil, only that it be SAE 10 wt. oil. General Electric publication GEH-982F, "Spring-Set Brakes, Thrustor Mechanism Type," specified that G-E No. 9621 oil be use for more extreme temperatures (range of -40°F to +150°F). The operator had been adding a 10 wt. motor oil, brand unspecified, to keep the oil at the proper level.

We strongly recommended that all lift operators be informed of the possible results of using the improper oil in the GE thrustor brake.

A three-step method of checking the operation of the automatic braking system is now being used:

1. Checking exactly as was done before.

2. Manually release the brake, with the machine stopped, using a 2x4 or bar which the operator keeps for this purpose. (I would suggest having the operator himself perform this check while observing the road movement closely.)

3. Observe the brake drum while the machine is cycled through at least five starts and stops. (This stop will vary from machine to machine.) The main drive shaft on this machine cannot be seen from the inspection door; therefore, it is necessary to observe from inside the Iron Horse. A chalk mark on the edge of the drum helps. Five things to look for are:

    a. Roll back. If the drum reverses itself after stopping, the brake is too loose. Since the backstop activates with less than a 10 degree reversal of the high speed shaft on this particular machine, and there is a 120:1 gear reduction between the high speed shaft and the low speed shaft, roll back due to an inoperative brake cannot be seen at the cable.

    b. Shoe chattering. Shoe chattering could be caused by many things, but is likely caused by poor adjustment.

c. Shoe contact. Shoes should contact the drum evenly with no gaps.

d. Pull release. The shoes should release to the point where no drag is apparent when the machine is moving.

e. Dirt and grease. The shoes and drum should be kept clean to maintain full braking power.

During an inspection, check and make sure that the operator understands how each of these units function.

Individual units will vary in their adjustment, but the fundamentals are the same. Thrustor brakes are spring-set units, with a motor device to release the brakes. They are designed so the braking torgue can be set to equal the maximum driving torque of the prime mover. This is the way they should be set.

Three adjustments can usually be made to these brakes: First, a spring adjustment; second, a gap adjustment; and third, a time delay adjustment. These adjustments should be made in this sequence. The procedures are:

1. Spring Adjustment. The spring adjustment is probably the most important as it determines the actual braking force applied to the machine. To make this adjustment, the torque of the prime mover is calculated from the formula:

$$T = \frac{HP \times 5250}{RPM \text{ (full load)}}$$

Using the curves on page 7 of General Electric publication GEH 982F, a spring length is determined for the particular brake involved. The nuts on the spring shaft are turned until the spring length measures the same as that selected from the curve. At this point you only have a potential for braking; the brake may not hold at all or it may be so tight the machine will not move. Don't worry about it and don't change this setting, but proceed with the other adjustments.

2. Gap Adjustment. The gap adjustment determines if the full rated torque can be developed, or if the brake is free when the thrustor is activated. "Gap" is the travel of the piston rods. A nominal gap is given for each model brake, but this should only be used as a starting point. This adjustment is usually a pair of nuts on the opposite end of the spring shaft from those used to adjust the spring length. These should be adjusted so that the brakes are just released with the motor on. The "Gap" measurement is the length of the stroke between the fully-off position and the fully-on position measured along the rods. This adjustment should be made at least annually since it compensates for lining wear.

3. Time Adjustment. Time adjustment is set at zero at the factory. This setting does not mean that application of the brake will be instantaneous, for it will still take about 10 seconds for a full stroke of the piston rod. It does give you a means to adjust the time to obtain smooth operation of the machine. If the operator says he had to back the brake off because it was stopping too abruptly, make sure he used the time adjustment -- not the "Gap" adjustment or the spring adjustment.

There are other adjustments on some of these brakes but the three adjustments covered are the most important.

All the pivots on the unit should be kept lightly oiled, and the shoes and drum kept free of grease and dirt. In combination with proper adjustment, a properly maintained brake should give years of trouble free operation.

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COEFFICIENTS OF FRICTION FOR SKI LIFT DRIVE SHEAVE LINERS

By Charles F. Dywer,
Staff Engineer, WO

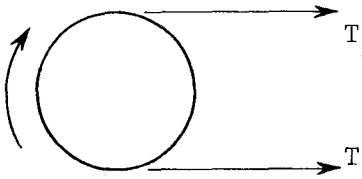
Our engineers reviewing ski lift plans and, to a degree, those inspecting lifts and tows are frequently concerned with potential slippage of aerial tramway and ski lift haulage ropes. Terminal sheaves which act as driving, braking, or holding sheaves must be so designed that the haul rope will not slip in the sheave groove during passenger operation. To a degree depending upon the type and use of the facility, this must be assured under all operating conditions:

- Rain, snow or ice on cable and drive sheave liner.
- Temperature and humidity extremes.
- Excessive or improper lubrication of wire rope.
- Abnormal acceleration or emergency braking.

The transmission of power by a rope drive is dependent on friction between the drive sheave liner and the wire rope. When the friction

value is exceeded, the rope will slip on the liner. The point at which slipping is impending or actually occurring is well established by the relationship:

Direction of Rotation on Drive Sheave



T_1 = Tension on tight rope

T_2 = Tension on slack rope

$$\frac{T_1}{T_2} \leq e^{uB}$$

e = Base of naperian system of logs = 2.71828

u = Coefficient of friction

B = Angle of wrap in radians (radian = 57.3°)

For conventional drive; one-half wrap (π radians = 180°).

$$\frac{T_1}{T_2} \leq e^{u\pi}$$

Note: The above formula has been simplified to eliminate the effect of centrifugal force. This consideration may be neglected for speeds under 25 feet per second. In making the above calculations, the following suggestions may be useful:

To raise e to a power by use of slide rule, set right index of C scale over value of e on LL2 scale, under value of power on C scale read value on LL2 scale.

Ex: $2.718^{.205 \times 3.142} = 2.718^{.628} = 1.875$

Using the coefficient of friction established for commonly used liner materials and the normal one-half wrap of a drive sheave, the corresponding values of T_1 over T_2 are as follows:

Sheave Liner	Coefficient of Friction	T_1/T_2
Steel or cast iron grooves	0.07	1.246
Leather	0.15	1.600
Rubber or Neoprene	0.20	1.875

In assigning a value for coefficient of friction on ski lift drive sheave liner material, a condition of a greasy rope is assumed. Note how these values change for alternate surface conditions:

	Greasy	Wet	Dry
Steel or cast iron	.07	.09	.12
Rubber or Neoprene	.20	.40	.50

The hardness of a liner material is of utmost importance. An increase in hardness decreases the coefficient of friction. Handbook and test data should be used when the hardness of standard materials is varied. An example: Aluminum liner materials are often assigned a coefficient of friction values of 0.20 when the Brinell hardness is equal to or less than 50.

Most design codes and standards regulate the potential for slipping by establishing maximum values for the coefficient of friction for various sheave liner materials. The current American National Standard Safety Requirements for Aerial Passenger Tramways (ANSI B77.1-1970) in Section 2.2.7.2.1 establishes the three values used in the example above. For other sheave liner combinations or materials, the values are to be determined to the satisfaction of the authority having jurisdiction. This brings about considerable discussion concerning the value of coefficient of friction to be assigned, particularly, to new liner materials. In establishing a value, the following theories and conditions should be considered. Each has a measure of relevance in determining a design coefficient of friction:

- The Euler-Eytelweyn theory that a coefficient of friction is not fixed but varies with the stress applied.

- The nature of lubrication which either can be assured or may be encountered during operation. Friction values vary from those established for dry friction, through those used for boundary (greasy) lubrication, to those established for complete (viscous) lubrication.

- The effect of non-fluid lubrication. This may react chemically with the solid surfaces to form an adhering film that attaches to the surface with a chemical bond.

- The effect of oxide or sulphide films on metal surfaces.

- The effect of surface finish (roughness).

Often test data furnished in support of an application for use of relatively high coefficients are obtained from laboratory or other controlled conditions. These are not realistic for the usual aerial

tramway application. Due to the unknown and uncontrolled conditions inherent in aerial passenger tramway applications and because of the serious consequences of rope slippage, it is imperative that design values be conservative. The limitations established by applicable codes and standards should be rigidly held in the interest of operational safety. The established limitations also assure uniformity among designers in the industry and facilitate the checking and comparison of designs and the inspection and enforcement of operating conditions. Establishing values for non-standard sheave liner materials or combinations should follow a thorough study. The precautionary wording being considered for the last paragraph of the ANSI B77.1, Section 2.2.7.2.1, is indicative of the concern: "For other sheave liner combinations, values shall be determined to the satisfaction of the authority having jurisdiction, but in no case shall the value exceed 0.205."

In Section 2.2.7.2.2 the above standard recognizes the less serious consequences of slipping that might occur on a surface lift or wire rope tow. It directs that a design preclude slipping, but no values for the drive sheave liner coefficient of friction are specified.

Current practice in the industry frequently uses values of 0.30; for example, on rubber-lined sheaves T_1/T_2 values of 2.5. or 3.0 are not uncommon. A determination of limitations here must be made on an individual basis considering the type of installation, the location, and the planned public use.

In summary, engineers involved with aerial tramways, ski lifts and tows should:

- Be aware of the potential for wire rope slippage and the serious consequences if this occurs. Designs using a lower terminal drive and design capacities at or near the capability of the rope are most suspect.

- Be cognizant of the manner in which coefficient of friction enters a drive sheave design.

- Be aware of the factors involved in determining an acceptable value for drive sheave liner coefficient of friction for a particular design.

- Be aware of the effect that maintenance and operating practices and conditions may have on wire rope slippage.

- Be aware of the values established in codes and standards for various liner materials and respect their limitations.

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