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soil, he can easily fall into holes which he was not able to see. We define the different types of forest soil according to their mother rock.

a. Clay soil: this is a particularly resistent soil when it is dry with a very high holding ability and on the other hand becomes very slippery when drentched with water and its holding power often diminuishes by considerable proportions. It is therefore necessary with such soil to organize the harvest of timber during the dry season, and if it is useful to work during the rainy season, it is nesessary to anticipate the need of devices which will permit the vehicles to pass over the worst places. The most classic forestry artifice is the autohauling winch placed on the front of the vehicle.

b. Humid soil: humid soil is most typically forestrial, it is covered with more or less decomposed humus, often mixed with a bed of leaves. It is equally the type of soil which one finds in marshy terrain. In order to pass over these types of terrain, it is necessary to use very large crawlers, which have a soil pressure of 100 g/cm .

c. Sandy soil: It often happens that massive forest regions are artificially developed in sandy soil regions. These terrains are often of very high holding power but they have insuffcient cohesion and when a vehicle starts up it very often becomes bogged down in the soil. Consequently, it is necessary, in order to move about on this type of terrain, to use large tires at very low pressure in such a way that this be done the least often possible. It is in fact scarcely recommended to utilize the crawlers in sandy soil because the silica of the sand is a powerful abrasive which will quickly wear down the steel joints of the crawler.

d. Rocky soil: rocky soil is that of which the auperficial humus has disappeared either by erosion or by repetitive passings. It therefore lacks the elastic element. We can supply it in a certain measure by utilizing relatively low pressurized tires, but in all cases it is recommended that the engines which move about on this soil be equipped with a scraping blade which permits it to reestablish the regularity of the mother rock which, very often, has very irregular forms making it quite difficult for classical engines. In order to define the technical characterists of the diverse soils, we must take into account a certain number of measures which are the following:

α → holding power: the holding power of the soil is measured with the help of an apparatus called a penetrometer; it is the limit of resistence starting from which the soil is deformed as soon as one excercs a given pressure on it. In general, soils have a holding power which varies from some hundred grams to ten kilos per cm .

β → resistance to movement: this can be defined as being the force per kilo parallel to the soil necessary to deplace one ton of given vehicle. It is expressed by this formula: R= K x W ... R is the resistence to movement of the vehicle per kilo; K is the coefficient of resistence to movement expressed in kilos per ton; and W is the weight of the vehicle in tons. This coefficient varies according to the type of soil and equally according to the whell system used, whether it's a question of iron wheels, wheels equipped with high or low pressurized tires, or crawlers; the annexed table gives a certain number of coefficients of resistence to movement in diverse conditions.

γ → resistence to sliding: this resistence is the horizontal force necessary to displace a body resting directly on the soil. There is a coefficient of resistence to movement which links this necessary force to the weight expressed in tons of the load to be displaced. The resistence varied in function to the soil and the form of the object to be displaced. It is a question of the occurence in logging of logs of which the variation of the diameter plays an important role and the way the logs are dragged; if they are totally dragged on the ground or if their forward end is raised, also cause a variation of this resistence in great proportions. The attached table gives according to the type of soil and the diameter of the logs and the way that they are dragged on the ground or lightly raised, the variation of this resistence, as we can see, varies from 150 to 700-800 kilos per ton of displaced logs.

δ → adherance coefficient: this last coefficient can be defined as the relation existing between available effort of the tractor and the weightresting on the motor elements of this same tractor. This relation is called the adherance coefficient. It is generally expressed in kilos in terms of the weight of the tractor expressed by the following formula: $F = \frac{EC}{W}$; F being the adherance coefficient in kilos per ton; EC being the effort on the hook of the tractor in kilos; W being the weight of the motor elements of the tractor expressed in tons. It is this coefficient which determines the efficiency of traction of the tractor. It also depends on the given soil and above all we see it predominately by its state of humidity. The following gives the variations of this adherance coefficient for tractors equipped with pneumatics or crawlers. As we can see, it varies from 170 kilos per ton to 560 kilos per ton for crawler tractors on dry black humus, for example.

1.4.2. The Silvicultural Conditions

After having examined the physical aspect of the soil, it is fitting to consider the forest that grows on this soil and which is the real goal of logging.

1) Diameter and height of the trees: It goes without saying that the number one factor to consider is the diameter and height of the trees, in other words, the unitary volume of the product to be handled.

2) Mode of forestry operation: According to the type of forest that we are dealing with, is it a question of a virgin forest, a regularly harvested forest or an underdeveloped forest, the conditions of logging will be very different because in the first case, as was previously stated , it will be necessary to create access roads in order to penetrate the forest mass, in the second case there are already roads but it is necessary to go looking for timber in the interior of the sometimes dense growth, because the operation will then be a silvicultural operation, that is to say a [illegible] situation in [illegible] the two [illegible] is

cases.

1.4.3 Economic Conditions

It is obvious that when one begins a study of the logging conditions, it is necessary to take into account all the parameters and particularly the economic parameters. The price of the finished product will be of course the result of all the logging costs but will be under direct dependence of the coat price of wood. This cost price varies from the function of ownership of the forest; if its a question of government or private forests, or if it is a question of forests for which we pay a simple royalty which is proportional to its surface without taking into consideration the actual forest productivity. All these elementa must be considered in order to calculate the coat price of the finished product.

It is also necessary to take into account the economic developement of the given country. Because, as it was previously stated, if there is absolutely no access road not only to the forest mass but alao to a port where the merchandise can be dispatched or a road or railway sometimes situated at a great distance away, the price of this firat investment ought to be taken into consideration in the calculations of the cost price of the raw material. It goes without saying that it would be normal in the case of very great investments of this type, that the community, country, state or county take charge of all or part of the financing in order to establish these roads.

1.4.4 Psychological Aspects

Besides these economic problems, one of the principle factors of success is the cost of human problems, and above all else the problem of manpower.

1) Manpower problems: It is fitting to determine right from the start of the study what the duration of the operation will be, and above all if the forest manpower will be seasonal or permanent. In the first case, we must forsee that the seasonal manpower will generally not be careful with the equipment and the material will suffer accordingly whereas the personnel assigned in a permanent fashion will be more cautious with the functioning and up keep of the machines. It goes without saying that we ought to try, when organizing the yard, to utilize personnel of the most permenant fashion possible, even if this necessates making changes in the form of personnel utilization , making roads or reafforestring, for example during one period of the year and executing felling and skidding during other periods. However, in certain countries, the climatic conditions; rain in the tropica, snow in scandinavia, make it so that there isn't a possibility of employing workers all year long and it is necessary to utilize seasonal manpower. Besides this important question of use of seasonal manpower or not, it is fitting to determine the type of the existing available manpower.

a/ in over-populated countries: in these countries, we often have an abundant manpower force, often cheap, sometimes even more economical than machines, such as in the Far East, but in other regions, in spite of the large population, forestry manpower is hard to find because it's a herd and relatively poorly paid trade. In this case, mecanization generally permits the revaluation of the profession. It is advisable to adjust the salaries to the obtained production. In any case, we must not forget that the forestry workers are often rustic and brutal with the machines.

b/ developing countries: in these countries we cannot generally find competent manpower and the manpower which could come from the machines' constructor country would cost three or four times the price that it would cost in the initial country. The local manpower that we could use would often only be aides, who would be able meanwhile to be trainedlittle by little and could occupy more and more responsible positions. Certain constructors, such as Catapillar, have done studies on the efficiency loss in yards in terms of the work organization. It was found that with a very experienced team who are well payed and properly supervised, the loss per work hour is four minutes, whereas with a new team which is not well co-ordinated and who are poorly paid, the hourly loss is about ten minutes.

2) Management of the harvesting: we can form a like reasoning in what concerns logging management in particular at the level of relations between work organizations, between the office and the enterprise, between the bosses and the workers themselves. The same american constructor caused a variation in the loss of minutes per work hour according to the quality of management, from three to seven minutes. We can even estimate that in certain developing nations these coefficients can be doubled. In general, we estime that with a coefficient of .85, the efficiency of a yard can be considered exceptional. With a .60 to .75 efficiency, very good to acceptable. An efficiency inferior to .50 means that the organization is defective.

3) Social Aspect: it is fitting, when one does a study on the eventual costs of a logging operation, to take into account the laws and customs, besides the conventions of the countries where one is; the laws and customs and in particular the social laws which can forbid a certain number of supplementary work hours, or oblige the use of sometimes very high taxes. On the other hand , the cost of social charges ought to-be equally taken into consideration because it varies by great proportions according to the country. The necessary accident insurances, not only for the work force but also for the engines, are also a point which varies considerably from country to country. Finally, the conventions, not only the social ones but also the work habits ought to be taken into consideration if we don't want to go way over our account and it is very often necessary to consider the work organization because if we establish a new work method, and it doesn't produce the expected results, the workers will very quickly revert to their old

habits in re-establishing a routine which will impose itself and will be very difficult to thwart.

2. Technical description and mode of utilization of tools and machines used in the forest

2.1) Manuel tools

→ The ax is one of the oldest tools which man has ever used; it is an excellent striking instrument; a mass attached to a handle which tenfolds the force of the individual hit.

→ Another striking tool simultaneously used with the ax is the cutting billhook, whose form varies according to the region, the most perfect form without being the italian one , with a nib in a hook form which permits not only the pruning and trimming but also the hauling of timber and facilitates its handling.

→ Another manuel tool that we cannot forget to mention is the wedge which serves to cleave the logs and is also used at the moment of felling, and its indispensable companion the maze. Along with the striking tools we can mention the "debarker", a sort of shovel which is pushed along the trunk.

→ In the second category of manuel tools are all the scrapeing instruments. These instruments have practically disappeared since the arrival of power saws which better replaced them. There still exists on the market a small saw for debranching which is mounted at the end of a handle and permits the limbing of trees up to four, five and even six meters.

→ Another series of tools are grippers and hooks, used for the manual handling of wood.

2.2. Power saw

Technical characteristics: the most common model of power saw is the saw with direct drive where the drive pulley is directly fixed by the intermediary of the centrifuge clutch on the crankshaft and the motors in these machines turn 6,000 and 10 to 12,000 rev. per minute, Given the diameter of the pulley which is around three to four cm., the corresponding speed in meters per second is from ten to twenty meters per second. The necessary power for a power saw depends on the effort with which one penetrates the wood with the blade. It requires a power of four to five HP. It is this power that one presently finds in the majority of the existing machines on the market. During the past few years the power saw has witnessed the coming of accessories to improve comfort; a scandinavian constructor, in particular, has developed a method of making the burned gas pass through the handle, so that in winter the logger can warm his fingers while working. It is now required in many countries to have a manual switch controlled by the worker which automatically triggers when the worker releases the machine.

2.3. Bunching

The most simple saw used to be the man-saw. bunching It was next replaced by the mechanical saw, which was for many years the only chain tool used regularly and in particular at sawmills. With the development of the power saw, it was the mechanical chain saw which imposed itself little by little for use in cutting timber. Meanwhile, for the timber destined for grinding in partioular, cutting machines were leveloped; some were portable and could circulate in the forest, they became very successful a few years ago, and now there is a vertical unity which cuts wood before stacking it for industrial use. Derived from these small cutting units have appeared, particularly in economically planned countries and countries with high levels of forestry production auch as the southern United States, veritable wood conditioning milla. In these mills, the trees are loaded and transported full length, passed by checkera who determine the quality of the tree and automatically orientate it to the cutting ahop which generally has a large number of saw which are operated automatically by the electroni brain of the most elaborate machines which permits the cutting of the tree to the optimum dimension according to its intrinsic technical quality.

2.4. The barking

The determination of the best place for the barking can be treated in a mathematical fashion: by knowing the cost of the barking, the cost of barking in the forest or the coat of industrial barking in regard to the transportation expenses in moving the timber between the different points where the said barking will take place. Studies have been done on this problem and the conclusions are that the best point is generally in accordance with the dimension of the timber and the employed technology.

→ Friction barking: the simplest machines which were destined, in the beginning to barking, were large barking drums in which the logs destined for the mill, in particular were introduced and the logs fell on each other during a certain number of rotations which depended on the elementary dimension of each piece of wood. This technique seems to have been abandonred to the more profitable scrapers.

→ Scrape barking : scrapers are those machines which turn around the tree while it is perpendicularlypenetrated in relation to the plane on which the tool is placed. These machines actually reached a great level of perfection and are certainly, on the world market, the machines which give the best results for the lowest cost price. They permit, in particular, selectioning in the sorting centers, as was said above, and can be adapted to each timber's dimensions according to the number of blades, the speed of the passing of the logs and therefore work in optimum effciency conditions.

→ Other models : Another friction machine is the friction head. While the logs describe a spiral movement under these heads . But the majority of this type of machine has been discontinued and replaced by blade heads which in fact do a very high quality barking, but they have the disadvantage, in comparison to their predecessor, of consuming part of the wood, which can reach three or four and even five percent.

2.5. Combined Machines :

Role: The comparitive study of the different phases of logging has quickly shown that if some among them can be better done by hand, others, to the contrary, were very slow, demanding a great part of the manpower and were relatively difficult to mecanize. If we examine the totality of the phases concerned with the harvesting of timber, we can rapidly note that limbing, for example, is an operation which requires up to 30% of the total harvesting time and seems very difficult to mechanize. When barking is necessary, it is equally well-known that barking is a fastidious and burdensome operation, because the effciency of the worker with the barker is low and mechanization in the forest, despite numerous attempts, quickly seems irrational. The efforts of the searchers firstly spanned the mechanization of a like barking operation. It is thus that the first combination machines that effectively functioned were the limber-buncher. These two operations represented up to 60% of the timber work-up time where as felling never represents more than 5% of this time, the rest being handling, regrouping, transporting, etc.

→ Limber-buncher: We saw above that the most important harvesting phase is the limbing. The constructors and the research institutes also tried in the beginning to mechanize this operation, which in the planting of conifers was rather simple to resolve. We site notably the "Arbomatik" machine and the Swedish "Sund" machine. But the veritable operational machines were the Swedish "Logma" and the Finnish "Pika". These last two machines took the trees that were manually felled and passed them through a metal belt where cutting tools limbed them by a hydraulique jack system which forced the trees through the mashine.

→ Feller-limbers: The following phase was to try to mechanize the the felling and to attach to the machine a limber similar to the ones developed on preceeding machines. The first feller-limber was the "Beloit-harvester" developed fifteen years ago in the United States and Canada. But this machine was monsterous and very costly. Other constructors put out other machines in the following years such as "Beloit" which had a hydraulic prunner in the front and a limber similar to those along the line of the machines sited above, that is to say simple blades which enclosed the tree while it was displaced by a hydraulic jack system. These diverse constructors put these machines on the market; we site "Timberjack", "Cemet", "Valmet", etc. However other constructors preferred to utilize a crane equipped with a hydraulic prunner and a head that did the limbing itself with wheels equipped with studs: the tree passed horizontally into the head and the branches are therefore cut off but this machine is generally not a barker. The principle constructor is the American firm Drott which has actually sold a large number of this type of equipment, and in Europe, there is the well-known constructor Poclain.

→ Stamper-feller: We can compare these modern evolutionary technics to the experiments that were recently conducted in Finland in particular into the recuperation of the stocks of the trees in order to augment in the proportion of 10 to 15% the lineer production of the forest plantings, and at the same time leave the soil more able to reefforest.

2.6. The Forestry tractor:

2.6.1 Technical description of the diverse types of tractors

- a) Four driving-wheel tractor:

The classic tractor which was used in the forest for numerous years was the tractor with four equal diameter driving wheels which were often even of equal drive which permitted the vehicle to have a very short braking range, and to be able once it was caught in a rut to easily get out thanks to the combined action of the front and back wheels.

b) Articulated steering tractor:

The advantage of this device is that it permits a relatively long engine to have a very short braking range. Also, if it falls into a pothole by a forward and backward movement called a "duckwalk" it can easily get its two front wheels out of the hole and refind a sufficient enough adherance to permit the vehicle to get out of the bad situation. The articulated steering tractors were not developed very long ago, for public works constructions and equally appeared in agriculture a while ago. It literally conquered the entire forestry market where it took the place of four driving-wheeled tractors in addition to a great number of crawlers. The articulated steering tractors are generally equipped with a rear winch and a forward leveling blade. The vehicle can be loaded with the help of a hydraulic crane called a forwarder, commonly used now for loading cut wood and even small logs. In the Scandinavian and North American forests this engine has been substituted for all other types of forestrial transport equipment.

c) Rigid crawler tractor:

The crawler was traditionally used for many years in tropical or virgin forests where it was necessary to make roadways in the mass in order to tkae out the exploitable products. These tractors were generally equipped with a powerful rear winch and diverse forward accessories such as a bulldozer blade.

d) Flexible crawler tractor:

The inconveniencs of what we call the classic rigid crawler is that when it moves about the forest the motor elements are not flexible enough to by-pass the obstacles it encounters. That is why a certain number of specialized constructors thought it preferable to use flexible forestrial crawlers, that is to say those which roll on oscillating tracks which permit it to literally eat up any encountered obstacle. These tractors were developed above all in Russia and Canada.

e) Articulated steering crawlers:

We have witnessed the appearance in the past few years of engines which have the advantages of both the articulated steering tractor and the crawler, this especially in oil excavation in Northern Canada. These devices are useful in forest terrains which have a particularly low holding power such as marshy zones or those which are inondated a great part of the year.

2.6.2. Accessories used in the forest :

a) Logging pans : the unloading pans are an accessory which was utilized quite commonly long ago in mountainous regions. They have unfortunately tended to disappear.

b) Logging arches : the logging arch is formed of two wheels and a sort of crane arm mounted on the wheels which is hooked onto the rear of generally a crawler tractor. This accessory was utilized for many years to execute logging by lifting the end of the logs , avoiding in this way dragging them on the ground and damageing them. The effort of the tractor was reduced thanks to this device from 30 to 40% in relation to the direct dragging on the ground.

c) Two wheeled loading device: is another wheeled forestrial accessory which is utilized behind relatively light tractors in order to transport heavy logs in particular cutting timber. The log is lifted off the ground and because of this the sliding traction effort is replaced by a rolling effort, that is to say divided by 20 or 30. (In French : Triqueballe)

d) Trailer with power drive: in order to transport cut up timber, farm trailers were used during many years and it is only in the past few years that we have witnessed the appearance of specifically forestrial power drive trailers. They were equipped with a crane, usually hydraulic, permitting the loading of the trailer and generally the wheels of the trailer were rendered power driven to facilitate movement in particularly difficult areas. It was these trailers equipped with cranes and power drive that were the originals of the first "Forwarders" where we replaced the farm tractor with motor elements situated at the front by a general farm tractor equipped simply with two wheels and reunited to the trailer by a system of jack articulator. The first engine constructed in this manner was the Swedish "Brunet" and "Robur" , soon followed by the Canadian "Treever". Presently, the french firm Cemet produces this type of device derived from farm tractors.

e) Afforestation material: the use of a farm tractor in the forest is not simply limited to harvesting. It can also serve usefully to prepare the soil before afforestation or to maintain afforested zones.

f) Public works material: we previously sited the ground breaking and leveling devices which are utilized in the forest generally on the crawler engines and which permit the opening of roadways and maintainence of them, operations hich are generally necessary as we have said several times for harvesting in virgin forests or unpenetrated forests.

2.7. The winch : winches are used in the forest as we have seen principally on the back of loading tractors and sometimes on the front when the winch assumes the role of emergency repair, actually an autohauling winch on the front of a tractor would permit it, if it were bogged down in the forest, to be able to extract itself under all circomstances. It is this technique which was used in particular by the American military vehicles during World War II.

Besides the utilization of winches on tractors, they also serve to encite cableways of either one or two cylinders, these engines permit the transportation of loads to sometimes considerable distances.

2.8. Handling engines in the forest : The handling of small timber particularlly in the forest has made considerable progress during the past ten years and we have literally substituted the loading worker by total mechanization, by the use of cranes and in particular hydraulic cranes mounted directly on the loading engine. We made reference to these engines when we described tractors and their trailers.

2.8.1. Forwarders : we described above, when we spoke of articulated and farm trailors, the device called the forwarder, which is in fact an auto motor engine carrying a crane which permits self-loading and unloading. It is important to point out that crane unloading is often used because it permits the foreman to preselect the timber.

2.8.2. Conveyor Belts : instead of using cranes, we have developed, in the last few years, small conveyor belts which are directly mounted on the trailers and permit the workers, when we are handling timber of small dimensions such as wood destined for charcoaling or for paper or board industry, to gather at ground level the heaps of wood that the workers can directly throw on the conveyor belts.

2.8.3 Hydraulic lifter and winch devices: for many years, the most common engine used for loading the trucks was the cable lifter.

2.9. Transport trucks :

2.9.1 Description of the different types of existing trucks :

We distinguish the diffarent models of trucks by their number of wheels or the number of axels. The multiplication of the carrying axels permits the diminuization of the unitary pressure on the ground and consequently to augment the load which can be transported.

2.9.2. Differe[illegible] of logging trailers: the logging trailer

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche is a type of trailer which is behind the route trailer inthe transport of full length logs. It is a special engine equipped with one or two axels which can be put empty on the tractor itself.

2.9.3 Braking and slowing down: it goes without saying that the braking of wood transport vehicles ought to be very firm. We will call our attention now to slowing down because when a loaded vehicle must descend long slopes, the normal iron brakes will heat up and loose, with this heating, their braking power. It is therfore necessary in this case that the vehicle be equipped with an emergency brake near the gearbox.

3. Telepheriques:

We class the different utilization techniques of the cables depending on the very complex methods described below:

3.1. Lost log cables: consist of a cable which is strung between two unlevel points such that one is on a cliff and one in a valley. The load of wood which is limited to about 10 kilos is fixed to the rope by a wooden hook slipped directly to the billhook. When the load arrives at the base of the valley, the hook jumps and is broken by a sort of olive attached to the same cable end the load is automatically unhooked.

3.2. Continuous Cables : are made up of one unique cable circulating on pulliee which support it and the loads are hooked, in this case, directly to the cable which plays the role of both the carrying cable and the tractor cable. This typr of cable is generally only used for unitary and relatively weak loads, such as unitary logs or small fagots.

3.3. Go-and-back cable : consists of two parallel cables on which circulates two cabin hooks joined by a cord passing on a high pulley and, in order to avoid alternative movemente, on another low pulley. This is the system currently used for people to ascend mountains, with a large cabin capacity. This type of device is relatively little used at this time in the forest because it calls for a relatively great instellation and it has a very limited output.

3.4. Tre -ceble: derived from the preceeding cableways, it is a very common forest model in southern Europe, in perticuler, called the tre - cableear. It is made up two carrying cables, one principle oneof a 20 to 25 mm. section and one auxiliary one having a 12 to 16 mm. section; these cables are mounted as those of industrial telepheriques on poles or supports generelly made of wood and are made up of a certein number of cars spaced a calculated distance apart according to the longest span of the cable. The cars are rejoined below on a veritable braking ground generelly situated at the highest station. These cables work in a discontinued fashion and are above all designed for the descent of logs in rough terrain regions.

3.5. Cable cranes/ Blondin: exist under numerous forms. The simplest was the one developed by Wyssen in Switzerland which consists of a simple car circulating on a slant and held in place by a cord wound around a winch at the highest station. When one wants the hook to descend the car, it need only stop it, make it do the inverse movement so that it automatically blocks itself on the principle cable. It unhooks at the same time a jaw, which frees the hook and it, if there is sufficient counterweight, can descend to ground level where another load can be harnassed. The Flodlin, on the other hand, is made up of one unique carrying cable and one simple car is displaced on the cable which is set into motion by a cord which passes by the car, descends by a pulley-block system to the hook and remounts to the car and goes on the return pulley to the other extremity of the cable. This way the car can be displaced all along the carrying cable and it can therefore eventually be mounted horizontally. The ascent and descent of the hook is done by a blockage car which is more or less ingenious. The most primitive method consists of having a second cable which displaces the car and therefore permits its mobilization to any point on the carrying cable, whereas the second cord permits the execution of the ascent and descent of the crane hook. Finally, certain constructors have tried putting a telecommanded electric or combustion motor in the car itself permitting the ascent or descent of a load from anywhere along the route of the carrying car.

3.6. <u>Cables which use ballons</u>: in rough terrain regions which have a convex profile, such as old mountains (Black Forest, Vosges, etc.), the use of telepheriques is rendered difficult because they always have a concave form. Also, certain researchers have tried for some time to use the ascent force of the ballons to permit the handling of the above ground load and from this fact permit the transportation over long distances whatever be the profile of the terrain. These materials were especially developed in the United States and a little in Russia, but do not seem to have passed the experimental stage.

3.7. <u>Helicopters</u> : we can also attach to timber harvesting by cable the contrivance which consists of using helicopters to load the timber. Experiments were done quite a few years ago on the use of engines of great ascentional power. Actually, certain military devices can carry loads of up to forty tons, which is largely sufficient for lifting the largest trees in the forest.

4. Other modes of transport:

4.1. Floating : The floating of wood is a technique which is still used in the Northern Hemisphere. In fact in these plains regions, the transport of wood by floating is traditionally one of the oldest methods which exists, we cite in Norway, for example, the floating association whose beginnings date back to the XII century. The traditional method is called the lost log method; that is to say that during the winter the timber is stocked onto the ice of the lake and when the ice is broken up later and lets the logs continue down the river, they are collected at its mouth where the transformation industry is usually situated. It is this very way that in Canada and also quite often in the Scandinavian countries, the forestry franchises correspond to the river bassin and the totality of the timber of the bassin can be dispatched by natural gravity to the papermill or sawmill in the valley below. When there are many important rivers and bassins and when several come into the same bassin, which is frequently the case in Scandinavia, a small metallic plaque or signia permits the wood sorters to orientate the timber towards each utilization sector. This operation is now simplified by veritable sorting centers of which certain ones in Russia are electronic and quasi-automatic and which permit the classification of timber not only by origin but also by quality and utilization.

4.2. Water transport : Water transport must not be confused with floating. It consists of transporting timber on light barges in canals which are made for the transport of industrial materials.

4.3. Railway : private tracks for the transport of timber were very frequent in the XIX century and the beginning of the XX century, especially in developing countries where a railway track generally costs less than a road and permits the exit of great tonnage of wood with excessively mediocre terrain conditions.

5. Method of calculating the cost price of forest jobs

5.1. Calculating the cost price of work material:

In all cost price calculations, we can consider three types of expenses: fixed costs, in the machine is in service or not.

proportional costs: which are proportional to the work of the machine and consequently to the hourly production: costs that are generally relative to the given enterprise and which vary according to the work organization and the state of development of the country where the logging is taking place.

5.1.1. Fixed costs :

→ 1. Depreciation or amortizement of material: Year after year a machine will loose its value. It is therefore fitting, when it becomes unuseable, that the owner refind the capital from the first day to replace the material which has become deficient. It is also fitting to determine during what period of time to redeem the machine. This estimation is very important because the hourly cost price of the machine depends greatly on the number of annually used hours. The number of employed hours of the machine is proportional to its productivity and its conditions of use. Usually, this period is determined by the moment when the repair costs become greater than the return costs. The simplest method is to consider the amortizement directly proportional to the time, which is called the linear method. The opposite method is a more rational one which consists of taking each year the actual value of the used material on the market, giving us a curve which moves out stringly to the right because it is an exceptional type. In the calculation of cost prices, it is preferable to take the hour as the unity and we will therefore have the amortizement, which will be calculated by the buying value less the eventual used material value divided by the total number of hours during which the machine is amortized.

It is fitting to remember that for certain machines, such as crawler tractors in particular, it is important, if we want to see the problem more closely, to amortize separatelt the crawler tracks and the tractor itself; the tracks being used up more quickly then the tractor. The same goes for the tires of great dimension which are actually used on public works engines. It is advisable to note that , in the amortizement of ma hines, it is necessary to take into account in all cases the age of the said machine, because even if it is used very little and therefore has a limited employed use hour, it is necessary to take into consideration that, at the end of a certain number of years, this machine may have totally lost its intrincic value, in spite of the little work it has done.

→ 2. One of the other factor which it is advisable to incorporate in the fixed costs are the capital interests necessary to buy a machine, which normally ought to be calculated in the remaining value of this capital progressively in accordance with the amortizement of the machine. Afterwards the insurances, taxes, garage costs, etc. must be incorporated.

5.1.2 Proportional costs : These costs consist of the maintenance and functioning costs. When we speak of vehicles, the maintenance cost of the rolling tracks can be taken separately from that of the vehicle. The maintenance cost of the vehicle itself are those that we know well in automobile materials: repair of mechanical parts, brakes, clutch, etc. These repairs are of equally important proportion to the machines: the telepheriques, the loading machines, etc.

Other maintenance costs are those of accessories which are attached for example to the tractor. If on one hand we must proportionally amortize the functioning of the tractor itself, we must also write a section for the cables, loading arches, etc.;that is to say all the accessories that work on the tractor.

5.1.3 Functional Costs:

→ 1. The energy dispensed by a machine for its functioning: this energy can either be in motor fuel or in electric kilowatts, in the case of machines driven by electric motors. In order to calculate the consumption of motor fuel of a tractor for example, we can use a theoretic motor curve, which gives a motor fuel consumption curve. But we must remember that with consumption in g/CVh. we must take minoration coefficient of 40 to 75%, according to the actual efficiency with which the engine preforms. In accessories for fuel motors, we cannot forget the lubricants, grease, all the commonly used materials which are often proportional costs to those of the fuel motors themselves. The proportion is about 20% and sometimes descends to 4 or 5% for tool machines.

→ 2. Salaries: the salaries are those of the worker who drives the engine but also of the auxilary services such as the greaser, the [illegible] work daily and [illegible] with the [illegible] maintenance of the given machine. It goes without saying that there is a repair shop and that this shop eventually actually does repairs, this ought to be indluded in the calculations.

5.2. Use of cost prices

Theoretic determination of the best mode of work:

Whenever we put into equation form the cost price of each phase of the logging operation that we realize, it is possible to compare them by a graphic or algebraic method. In fact, the majority of the cost prices are seen as a first degree equation. This way we can give an accounting to the origins of the fixed costs and a proportional part which are the proportional costs on which the angular coefficient varies according to their relative importance to the given production. In general we express the cost price according to the production in m^3, according to the parameter, whatever be the loading distance, the thickness of the timber, etc. and accordingly the costs are presented in the form of a right which we can put into a graphic system of reference. In comparing a certain number of work methods for a given logging operation, we are going to discover that one method is best from a certain point on and another method becomes more economical from a different point on; and we will find ourselves enclosed by a certain number of curves which finish by encircling the problem, and we can find the optimal conditions possible to organize a logging operation in order to get the best economic results. Such a study can, of dourse, actually be done by computers to which it is necessary to give linear components of each given case. In this fashion we can determine the best theoretic method of work system in a given case.

This analyse can, for example, determine the implantation of a network of roads or a telepherique system in a forest mass and permits in particular the determination in advance of what will be the inconveniences and advantages of the two forseen methods from the viewpoint of simply productivity. It is fitting to remember, meanwhile, that it is necessary to always keep in mind the social problems that can be presented by the use of mechanical materials.

6. CONCLUSIONS

The choice of material and of harvesting methods to be used for logging operations can be determined as we have just seen by calculation done with the help of computers. But this advanced method ought to be prepared and analysed by technicians and engineers who ought to have the necessary knowledge in order to be able to propose the best methods and machines and above all the social and psychological conditions of the population concerned by these projections.

In effect, these human problems are not incorporatable in the calculations and it is the qualities of common sense and individual sensitivity which often will determine the success or failure of the project.

We hope that all of you who have taken this course knew how to extract the essentials of the doctrinal teachings which were dispensed to them and that it has been applied in such a fashion that it is a useful generator giving satisfaction to the greatest possible number of individuals.

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SELECTION OF FORESTRY EQUIPMENT*

by

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* The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

** Expert in forestry equipment.

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CONTENTS

1. Generalities

1.1. Definition of the Logging

In numerous countries of the world, logging is situated between industry and agriculture. We don't quite know to which section it should be connected. Indeed, it is a question of mobilizing a vegetable product and of passing it from the forest stage, essentially an agricultural stage, to that of industrial transformation, which is the sawmill or chemical utilization mill. This ambiguity makes the definition of logging rather complex. It is a question of successive operations which range from the felling of the tree to the final step at the point of industrial utilization. These operations require the use of often rustic manpower, who must often accept to live in precarious conditions in the middle of massive and sometimes important woodlands, in often inhospitable regions such as high mountains, under working conditions that ressemble those of Public Works, and are often intamitely mixed with them, particularly in virgin forest regions. In this case, it is often in fact necessary to execute the lay-out and realization of roadways that permit the exit of forest products.

It is equally frequent in the very rough terrain regions, that the loggers have recourse to cableways or telepheriques, which requires very particular knowledge.

The following phases of logging consist of transporting a material which is relatively difficult to handle and of progressing it sometimes over very long distances to the point of industrial utilization. It is essentially a question of functions which are integrated with those of the transporters.

Finally, at any given place of load rupture, frequently the good productivity organization requires the classification of products with their more or less automatic transformation. The large, modern lumberyards are also part of the logging operation.

Whereas only a few years ago the trade of a lumberjack was considered a difficult, and particularly pitiful one, for some time now an incessant revolution towards the complete mecanization of forestry operations has made it so that there is little by little a mutation towards the utilization of more and more specialized manpower and consequently towards a more and more elevated standard of living. This consideration is an important one, because in a trade that was considered outcast just a few decades ago, the logging trade and the logger have become more and more attractive to the younger generations.

1.2. The different phases of logging

Definition: We call a phase any operation which consists of executing a job without the need of changing tools; for example, the felling of a tree encompasses a first phase: the actual job a felling is done in using a power saw and once the tree is felled, the operation of limbing, requiring the use of another generally manual tool or lighter power saw, is considered a different phase from the first one. Bunching the wood is the third phase and skidding is the fourth. The stacking of the wood and the bunching of timber in order to execute this operation is an auxilliary phase. After the skidding, the timber is stacked along the roadside: this is a null phase. It is the stopping point in the forestry operations; on the other hand, the loading of the logs onto the trucks is considered a phase and afterwards the transport of the logs another phase; the unloading at the arrival point is often the final phase unless there is to be retransportation by another mode such as railway or barge.

1.3. Operational analyse of the time distribution

The different phases, as they have just been described above, were the objects, by many specialized institutions, of systematic studies of their respective time. Without going into detail on these studies, we can retain that the felling operation generally only represents a small percentage of the total logging time, whereas the burning, for example, of the small limbs and branches, can represent up to 15% of this total time.

To this analyse, it is fitting to apply a cost coefficient which depends on the material used during each given phase. For exemple, the classic felling operation with a power saw costs the salary of the worker who executes the job plus the reasonable amortization of the machine and its hourly utilization cost, that is its hourly consumption of fuel oil and the cost of required repairs per hourly use.

When we speak of the skidding operation, the unitary cost per work hour is evidently much higher, because in addition to the salary of the driver and possibly his assistant, it is advisable to take into account the amortization of the skidder plus its functioning cost, which of course can be up to 10 or 20 times the cost of the driver's salary.

In taking each phase, by multiplyin the time apent for a given operation by the hourly cost of each technical process used, we can determine the total cost of the operation from the forest to the mill. And a comparison of the different phases can be done by linear programmimg or better yet by computer.

The conclusions of such an analyse permit the projector to determine the best methodto employ in order to exploit a given forest. But, in addition to these theoretic calculations, it is fitting to take into consideration the restraints which encompasa the problem of logging and are generally resulting from the technology used for the proposed job.

1.4. Definiton of restraints

There are four types of restraints: physical, silvicultural and economic and it is advisable to not neglect the psychological aspect.

A) The physical conditions:

1.41 The physical conditions

1) The general lay-out of the region:

a. Mountains: In mountaneous regions, the slope of the terrain is the dtermining factor for the choice of materials to be used. For slopes under about 20-25%, it is not reasonable to utilize autopropulsing vehicules which circulate on the ground, crawlers can work on 30 and even 35% slopes. Wheel skidders should generally not be used for slopes above 20% in oder not to risk the rupture of stability. In the case where we have to work on greater slopes, we would naturally resort to the utilization of cable systems or telepheriques, assisted a bit by ba[illegible] or helicopters. In the case where we use automotor vehicules, the slope [illegible] the vehicle [illegible] determination of its center of [illegible], [illegible] were required to make the vehicle climb the slope will often [illegible] a determining criterion for the choice of an engine. It is in fact indispensable in a [illegible] the tractor with [illegible] cargo be able to climb the slopes in the best speed and adherance conditions. We would naturally try to use gravity for skidding the loads and as often as possible we would try to organize the yards in such a fashion that the engines move in the direction of the slope rather than climb them. However, it is fitting to observe that in the case of utilization of cable systems, or in particular cable cranes, it is easier to work in ascending the loads rather than trying to descend them, because in the case of pulling the logs towards the top, they have a tendancy of being pulled from the soil, whereas in the inverse they slip and risk floundering in the soil. It is also advisable to think about the altitude, the motors have an inferior effeciency to that which they have at sea level because of the rarefication of oxygen in the air. The loss of power which is 10 - 15% between 800 and 1500 meters reaches 30% when the engines are at an altitude of 3000 meters above sea level.

b. Plains: When we find ourselves in conditions of exploitation on relatively flat terrainard where the problems of slope are no longer preponderant, it is the state of the soil which becomes the determining element for the choice of transport vehicle. In fact, if on the dry terrains the problems of adherance are hardly of prime importance, as soon as we must work on marshy terrains, very humid or staying humid most of the year, these problems are so important that in certain cases, and it's the case in certain flat regions of Russia, the technicians prefere to utilize traction cables at ground level rather than to adventure vehicles which must almost be amphibious. By the same token, in these regions which equally exist in the south of the United States, in Florida or tropical regions, the railway was for a long time the most rational mode of penetration, costin in fact less than the established routes and having a proprovisional character that well served the episodical exploitations of the forests.

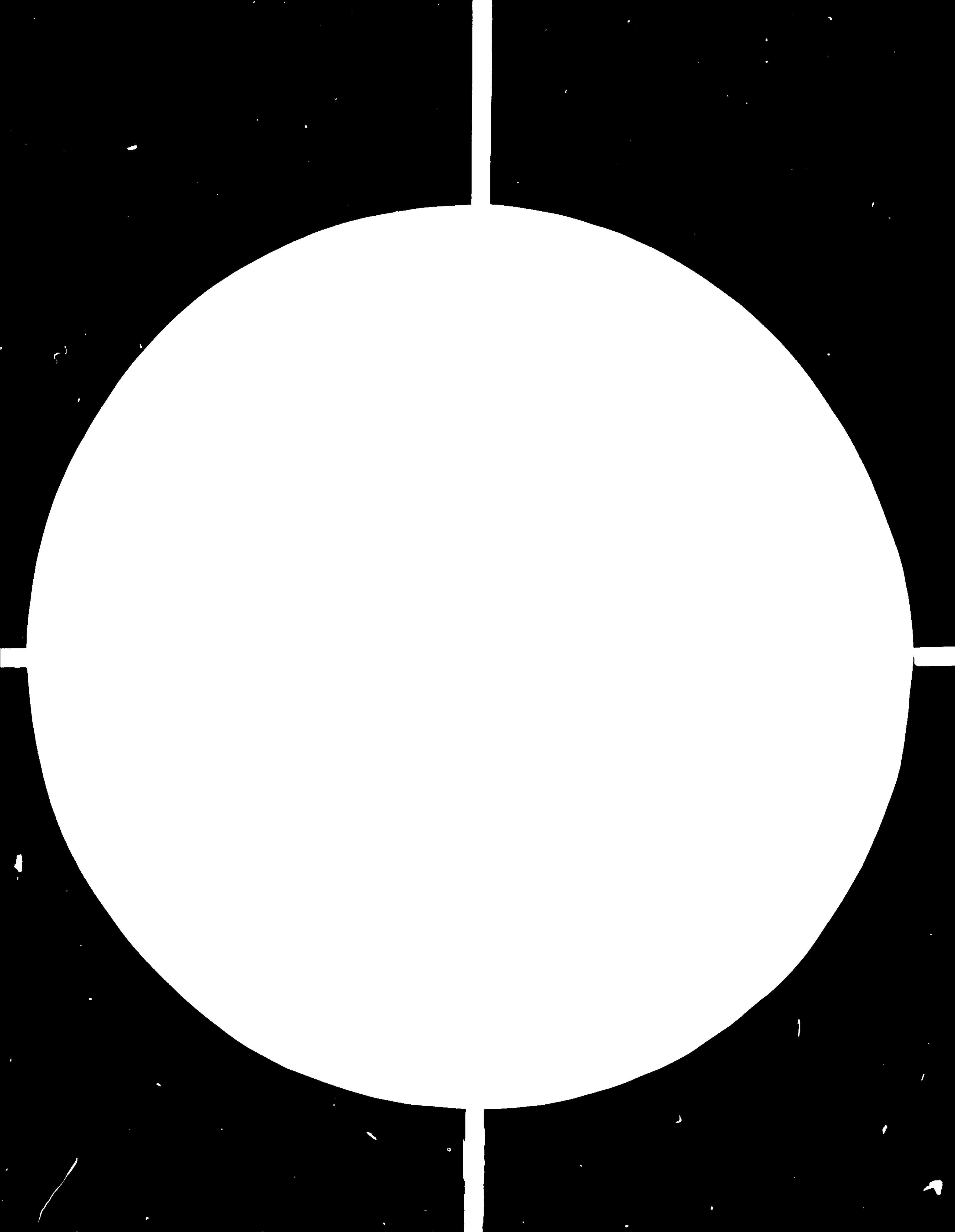
It is advisable finally to site the particular cases of artificial plantation of trees in rows which requires, when we want to preserve the reserved trees, a meteriel specially adepted to this specific cartesian exploitetion.

2) The climate

The first criteria on the subject of climate is the veriation of temperature. It is fitting to remember, as was for the eltitude, that according to the tempereture of the surrounding air, the efficiency of the motors veries in great proportions, due to the rareficetion of oxygen in the warm air. We estimate that between 30 and 50°C, there is a veriation of about 25% in the efficiency of the motors. In addition, it is often forgotten that the climate has a more spectacular influence on the stete of the soil which is in direct reletion to the instantanious climatic conditions, In cold regions such as Siberie, the Scendinavian countries or Northern Canada, snow becomes an aide in exploiting the timber because it permits the forming of routes on compressed or even frozen snow on which we can either directly pull the loads or use a sled, and considerable quantities of timber can be moved with an excessively weak coefficient of friction. In temperate climetes the possibility is null and the action of the climate slows up work during the rainy period but above all transforms the soil, which usually has a sufficient holding ebility, into a particularly unfevorable ground for the transport or passage of vehicles and reduces, because of this fact, the period of time when exploitation, or rather the skidding of wood, is profitable. One other similar observation should be made for the countries in a tropical climate region, because in fact, in these regions the rainy season forbids, generally for a long period of time, the penetration of the forest by mechanical engines and the totality of transport must be concentrated on the dry season when the holding ability of the soil permits the passage of heavy engines. Finally, one last point pertains to the climatic conditions in the wind factor. In fact, this last factor can be, in certain rough terrain regions or along the sea, a preponderant element to the prohibition or slow-up of the exploitation of the timber. On the other hand, the forest operations planner ought to, in almost all cases, take into account the presence of the wind factor when he orientates cuttings and particularly clear cuttings, in order to avoid that by unexpected wind storms the yard doesn't become entangled with windfall timber.

3) The soil

Forest soil, contrary to agricultural soil, is generally formed from the decomposition of leaves of needles which forms a more or less thick humus layer which lies directly on the mother rock, whereas in agriculture, there is on the surface a layer of cultivated plant roots which form an excellent support for the adherance of the transport engines. In other terms, the forest soil is presented to the driver as being a surface cluttered with destroyed vegetation which masks the real conditions of the under soil, and if the driver doesn't have a good knowledge and a certain experience with driving on this type of



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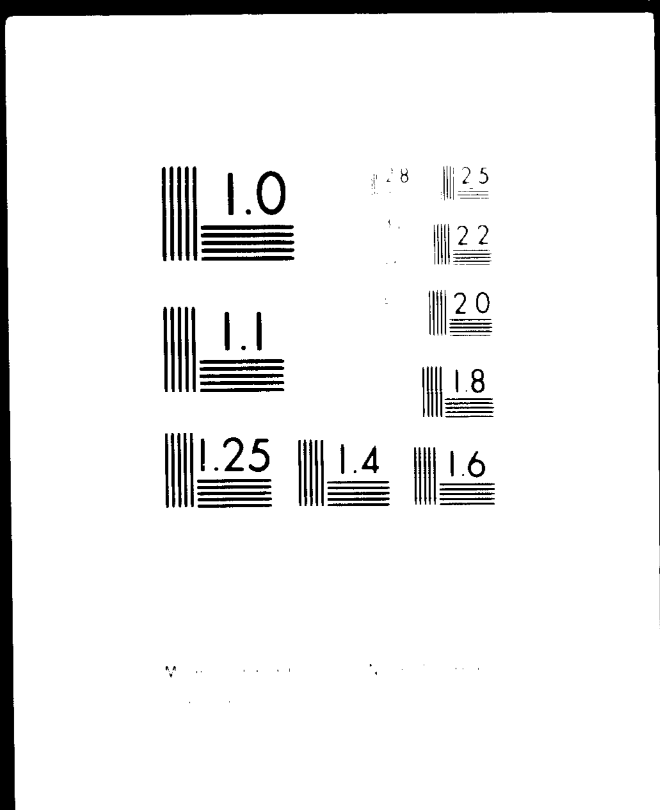

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b) Humid soil: humid soil is most typically forest trail which is covered with more or less decomposed humus, often mixed with a bed of leaves. It is similar to the type of soil which one finds in marshy ground. In order to pass over this type of terrain, it is necessary to use very large crawlers tractor which have a soil pressure of 100 g/cm.

c) Sandy soil: It often happens that massive forest regions are artifically developed in sandy soil areas. This type of ground quite often has good holding power but insufficient cohesion and when a vehicle starts in motion it suddently becomes bogged down in the soil. Consequently, it is necessary, in order to move about on this type of terrain, to use large tires with very low pressure. It is also not recommended to utilize the crawlers tractor in sandy soil because the silica of the sand is a strong abrassive which will quickly damage the steel joints of the equipment.

d) Rocky soil: rocky soil is that of which the superficial humus has disappeared either by erosion or by repetitive travel. It, therefore, lacks the elastic element. This can be utilized to some extent by using relatively low pressurized tires, but in all cases it is recommended that the engines which move about on this soil be equipped with a scraping blade to allow for the smoothing out of the ground surface which develops some irregular forms. In order to def[illegible]ne the technical c[illegible]aracteristics of the diverse soils, it is necessary to take into account number of measures which are as follows:

- holding power: the holding power of the soil is measured with the help of an apparatus called a penetrometer; it is the limit of resistence starting from which the soil is deformed as soon as one exerts a given pressure on it. In general, soils have a holding power which varies from some hundred grams to ten kilos per cm.

- resistance to movement: this can be defined as being the force per kilo parallel to the soil necessary to deplace one ton of given vehicle. It is expressed by this formula: $R = K \times W$ ... R is the resistance to movement expressed in kilos per ton; and W is the weight of the vehicle in tons. This coefficient varies according to the type of soil and equally according to the wheel system used, whether it is a question of iron wheels, wheels equipped with high or low pressurized tires, or crawlers; the annexed table gives a certain number of coefficients of resistance to movement in diverse conditions.

- resistance to sliding: this resistence is the horizontal force necessary to displace a body resting directly on the soil. There is a coefficient of resistence to movement which links this necessary force to the weight expressed in tons of the load to be displaced. The resistence varies in function to the soil and the form of the object to be displaced. It is a question of the occurence in logging of material of which the variation of the diameter plays an important role and the way the logs are dragged; if they are totally dragged on the ground or lightly raised, the variation of this resistence, which as we can see, varies from 450 to 700 - 800 kilos per ton of displaced logs.

- adherance coefficient: this last coefficient can be defined as the relation existing between available effort of the tractor and the weight resting on the motor elements of this same tractor. This relation is called the adherance coefficient. It is generally expressed in kilos in terms of the weight of the tractor expressed by the following formula: $F = \frac{EC}{W}$; F being the adherance coefficient in kilos per ton; EC being the effort on the hook of the tractor in kilos; W being the weight of the motor elements of the tractor expressed in tons. It is this coefficient which determines the efficiency of traction of the tractor. It also depends o the given soil a . above all we see it predominantly by its state of humidity. The following gives the variations of this adherance coefficient for tractors equipped with pneumatics or crawlers. As we can see, it varies from 170 kilos per ton to 560 kilos per ton for crawler tractors on dry black humus, as an example.

1.3.2 The silvicultural conditions

After having examined the physical aspect of the soil, it is necessary to consider the forest that grows on this soil and which is the real goal of logging.

(1) Diameter and height of the trees: It goes without saying that the number one factor to consider is the diameter and height of the trees, in other words, the unitary volume of the product to be handled.

(2) Mode of forestry operation: According to the type of forest that we are dealing with, it is a question of a virgin forest, a regularly harvested forest or an underdeveloped forest, the conditions of logging will be necessary to create access roads in order to penetrate th forest

mass, in the second case there are already roads but it is necessary to go looking for timber in the interior of the sometimes dense growth, because the operation will then be a silvicultural operation, that is to say a mixed situation in comparison to the two previous cases.

1.3.3 The economic conditions

It is obvious that when one begins a study of the logging conditions, it is necessary to take into account all the parameters and particularly the economic parameters. The price of the finished product will be of course the result of all the logging costs but will under direct dependence of the cost price of wood. This cost price varies from the function of ownership of the forest; if it is a question of government or private forests, or if it is a question of forests for which we pay a simple royalty which is proportional to its surface without taking into consideration the actual forest productivity. All these elements must be examined in order to calculate the cost price of the finished product.

It is also necessary to take into account the economic development of the given country. Because, as it was previously stated, if there is absolutely no access road not only to the forest mass but also to a port where the merchandise can be dispatched or a road or railway sometimes situated at a great distance away, the price of this first investment must be taken into consideration in the calculations of the cost price of the raw material. It goes without saying that it would be normal in the case of very large investments of this type, that the community, country, state or county take charge of all or part of the financing in order to establish these roads.

1.3.4 The psychological aspects

Besides these economic problems, one of the principle factors of success is the cost of human problems, and above all else the problem of manpower.

(1) Manpower problems: It is necessary to determine right from the start of the study what the duration of the operation will be, and above all if the forest manpower will be seasonal or permanent. In the first case, we must assume that the seasonal manpower will generally not be careful with the equipment and it will suffer accordingly, whereas the personnel assigned on a permanent basis will be more cautious with

the functioning and up-keep of the equipment. It is always best if at all feasible when organizing the yard, to utilize personnel of the more permanent type, even if this necessitates making changes in the form of personnel utilization, making roads or engaging them in reforestations for example, during one period of the year and involving them in felling and skidding during other periods. However, in certain countries, the climatic conditions; rain in the tropics, snow in Scandinavia, make it so that there is no such possibility of employing workers all year long and it is, therefore, necessary to utilize seasonal manpower. Besides this important question of use of seasonal manpower or not, it is necessary to determine the type of the existing available manpower.

a) In over-populated countries: in these countries, we often have an abundant man power force, often cheap, sometimes even more economical than machines, such as in the Far East, but in other regions, in spite of the large population, forestry manpower is hard to find because it is a hard and relatively poorly paid trade. In this case, mechanization generally allows for the revaluation of the profession. It is advisable to adjust the salaries to the production output in any case, we must not forget that the forestry workers are inclined to be rough with machines and equipment.

b) Developing countries: in these countries we cannot normally find competent manpower and the manpower which might come from the country in which the machine was manufactured would cost three or four times the price that it would cost in the initial country. The local manpower that we could use would only be in the capacity of helpers who would meanwhile be able to be trained little by little and could accept more and more responsible positions. Certain manufacturers have done studies on the efficiency loss in yards in terms of work organization. It was found that with a very experienced team who are well paid and properly supervised, the loss per work hour is four minutes, whereas with a new team which is not well co-ordinated and who are poorly paid, the time loss is about ten minutes per hour.

(2) Management of the harvesting: we can form a like reasoning in what concerns logging management in particular at the level of relations between work organizations, between the office and the enterprise, between the bosses and the workers themselves. The same American manufacturer developed a variation in the loss of minutes per work hour according to the quality of management, from three to seven minutes. We can even estimate that in certain developing nations these coefficients can be doubled. In general, we estimate that with a coefficient of .85, the efficiency of a yard can be considered exceptional. With a .60 to .75 efficiency, very

good to acceptable. An efficiency inferior to .50 means that the organization is unproductive.

(3) Social aspect: it is essential, when one does a study on the overall costs of a logging operation, to take into account the laws and customs, besides the conventions of the countries where one is; the laws and customs and in particular the social laws which can forbid a certain number of supplementary work hours, or the imposition use of sometimes very high taxation. On the other hand, the cost of social charges ought to be equally taken into consideration because it varies by large proportions according to the country. The necessary accident insurances, not only for the work force but also for the machinery, are also a point which varies considerably from country to country. Finally, the conventions, not only the social ones but also the work habits need to be taken into account if we do not want to go away over our account, besides which, it is often necessary to consider the work organization, because if we establish a new work system, and it does not produce the expected results, the workers will very quickly revert to their old habits in re-establishing a routine which will impose itself and be very difficult to change.

2. Technical description and method of utilization of machines and tools used in the forestry operations

2.1 Manual tools

The axe is one of the oldest tools which man has ever used, it is an excellent striking instrument; a sharp bladed mass attached to a handle which tenfolds the force of the individual hit.

Another striking tool simultaneously used with the axe is the cutting billhook, the form of which varies according to the region, the most perfect form without being one with a nib in a hook form which permits not only the pruning and trimming but also the hauling of timber and facilitates its handling.

Another manual tool that we cannot overlook mentioning is the wedge which serves to cleave the logs and is also used during felling operations, and its indispensable companion the adze. Along with the striking tools we can mention the "debarker", a sort of shovel which is pushed along the tree trunk.

In the second category of manual tools are all the scraping instruments. These instruments have practically disappeared since the arrival of power saws which replace them. There stil exists, however, on the market a small saw for debranching which is mounted at the end of a handle and permits the limbing of trees up to four, five and even six meters.

Another series of tools are grippers and hooks, used for the manual handling of wood.

2.2 Power saws

Technical characteristics: the most common model of power saw is the saw with direct drive where the drive pulley is directly fixed by the intermediary of the centrifuge clutch on the crankshaft and the motors in these machines turn 6,000 and 10 to 12,000 rev. per minute. Given the diameter of the pulley which is around three to four cm., the corresponding speed in meters per second is from ten to twenty meters per second. The necessary power for a power saw depends on the effort with which one penetrates the wood with the blade. It requires a power of four to five HP. It is this power that one presently finds in the majority of the existing machines on the market. During the past few years the power saw has been the subject of numerous accessories to improve comfort; a scandinavian manufacturer, in particular, has developed a method of making the burned gas pass through the handle, so that in winter the logger can warm his fingers while working. It is now required in many countries to have a manual switch controlled by the worker which automatically triggers when the worker releases the machine.

2.3 Bunching

The most simple saw used to be the manually operated cross cut saw was next replaced by the mechanical saw, which was for many years the only chain type tool used regularly and in particular at sawmills. With the development of the power saw, it was the mechanical chain saw which has grown very popular for use in cutting logs and timber. Meanwhile, for the timber destined for grinding in particular, cutting machines were developed; some were portable and could function throughout the forest, they became very successful a few years ago, and now there is a vertical unit which cuts wood before stacking it for industrial use. Derived from these small cutting units have appeared, particularly in economically planned countries and countries with high levels of forestry production such as the southern United States, veritable wood conditioning mills. For these mills, the trees are loaded and transported full length, passed by checkers who determine their quality and automatically direct it to the cutting shop which is required with a large number of saws, operated automatically by an electronic brain with the most elaborate designed machines which allows the cutting of the tree to the optimum dimension according to its intrinsic technical quality.

2.4. <u>The barking</u>

The determination of the best place for performing the barking can be treated in a mathematical fashion: by knowing the cost of the barking, the cost of barking in the forest or the cost of industrial barking in regard to the transportation expenses in moving the timber between the different points where the said barking will take place. Studies have been done on this situation and the conclusions are that the best point is generally in accordance with the dimension of the timber and the employed technology.

Friction barking: the simplest machines which were introduced in the beginning of log barking, were large barking drums in which the logs destined for the mill, were fed and the logs fell on each other during a certain number of rotations which depended on the elementary dimension of each piece of wood. This technique seems to have been abandoned in favour of the more profitable scrapers.

Scrape barking: scrapers are those machines which operate around the tree while it is perpendicularly penetrated in relation to the plane on which the tool is placed. These machines actually reached a great level of perfection and are certainly, on the world market, the machines which give the best results for the lowest cost price. They allow selectioning in the sorting centers, as indicated above, and can be adapted to various dimensions of timber, according to the number of blades, the speed of the passing of the logs and operate with optimum efficiency.

Other models: another friction machine is the friction head, where the logs are subject to a spiral movement under the heads. Unfortunately the majority of this type of machine has been discontinued and replaced by blade heads which perform a very high quality barking job, but they have a disadvantage, in comparison to their predecessor, of consuming part of the wood, which can conceivably reach three or four and even five per cent.

2.5 Combined machines

Role: The comparative study of the different phase of logging has quickly indicate that if some among them can be better done by hand, others, on the contrary, were very slow, demanding a great part of the manpower and were relatively difficult to mechanize. If we examine the totality of the phases concerned with the harvesting of timber, we can readily note that limbing, for example, is an operation which requires up to 30 per cent of the total harvesting time and seems very difficult to mechanize. When barking is necessary, it is equally well-known that barking is a fastidious and burdensome operation, because the efficiency of the worker with the barker is low and mechanisation in the forest, despite numerous attempts, quickly seems irrational. The efforts of the researchers initially spanned the mechanisation of a like barking operation. It is thus that the first combination machine that effectively functioned were the limber-buncher. These two operations represented up to sixty per cent of the timber work-up time whereas felling never represents more than five per cent of this time, the rest being handling, regrouping, transporting, etc.

Limber-buncher: We have noted above that the most important harvesting phase is the limbing. The manufacturers and the research institutes also tried in the beginning to mechanize this operation, which in the planting of conifers was rather simple to resolve. We mention particularly the "Arbomatik" machine and the Swedish "Sund" machine. But the veritable operational machines were the Swedish "Logma" and the Finnish "Pika". These last two machines took the trees that were manually felled and passed them through a metal belt where cutting tools limbed them by a hydraulic jack system which forced the trees through the machine.

Feller-limbers: The next phase was to try and mechanize the felling and to attach to the machine a limber similar to the ones developed on preceeding machines. The first feller-limber was the "Beloit-harvester" developed fifteen years ago in the United States and Canada. But this machine was monsterous and very costly. Other manufacturers put out other machines in the years following such as "Beloit" which had a hydraulic Pruner in the front and a limber similar to those along the line of the machines sited above, that is to say simple blades which enclosed the tree while it was dispalced by a hydraulic jack system. These diverse manufacturers preferred to utilize a crane equipped with a hydraulic Pruner and a head that did the limbing itself with wheels equipped with studs: the tree passes horizontally into the hea and the branches are removed but this machine is actually not a barker. The principal manufacturer is the American firm Drott which has actually sold a large number of this type of equipment, while in Europe, there is the well-known manufacturer named Poclain.

Stumper-feller: We can compare these modern evolutionary techniques to the experiments that were recently conducted in Finland, into the recuperation of the stocks of the trees in order to recover in the proportion of ten to fifteen per cent the linear production of the forest plantings, and at the same time leave the soil more able to reafforest.

2.6 The forestry tractor:

2.6.1 Technical description of the diverse types of tractors

a) Four driving-wheel tractor:

The popular tractor which was used in the forest for numerous years was the tractor with four equal diameter driving wheels which were often even of equal drive thereby permitting the vehicle to have a very short braking range, and to be able once it was caught in a rut to easily get out thanks to the combined action of the front and back wheels.

b) Articulated steering tractor:

The advantage of this device is that it permits a relatively long engine to have a very short braking range. Also, if it falls into a pot-hole by a forward and backward movement called a "duckwalk" it can easily get its two front wheels out of the hole and secure sufficient enough adherance to permit the vehicle to get out of the bad situation. The articulated steering tractors were only developed a short time ago for public works construction and later appeared in the agriculture field shortly thereafter. It literally conquered the entire forestry market where it took the place of four driving-wheeled tractors, in addition to a great number of crawlers tractors. The articulated steering tractors are equipped with a rear winch and a forward levelling blade. The vehicle can be loaded with the help of a hydraulic crane called a forwarded, commonly used now for loading cut wood and even small logs. In the Scandinavian and North American forests this machine has been substituted for all other types of forestry transport equipment.

c) Rigid crawler tractor:

The crawler tractor was originally used for many years in tropical or virgin forests where it was necessary to develop roadways in order to remove the exploitable products. These machines were equipped with a powerful rear winch and diverse forward accessories such as a bull-dozer blade.

d) Flexible crawler tractor:

The drawback of what we call the rigid crawler is that when it moves about the forest the motor elements are not flexible enough to by-pass the obstacles it encounters. That is why a certain number of specialized manufacturers thought it best to use flexible type crawlers, that is to say those which roll on oscillating tracks which permits the machine to literally eat up any encountered obstacle. These tractors were developed only in Cananda and Russia.

e) Articulated steering crawlers:

We have witnessed the appearance in the past few years of machines which have the advantages of both the articulated steering tractor and the crawler, this especially in oil excavation in Northern Canada. These devices are useful in forest terrains which have a particularly low holding power such as mershy zones, or those which are inundated a great portion of the year.

2.6.2 Accessories used in the forest:

a) Logging pans: the unloading pans are an accessory which was utilized quite commonly long ago in mountaineous regions. They have unfortunately tended to disappear.

b) Logging arches: the logging arch is comprised of two wheels and a sort of crane arm mounted on the wheels which is hooked usually on to the rear of generally a crawler tractor. This accessory was utilized for many years to execute logging by lifting the end of the logs, avoiding in this way dragging them on the ground and damaging them. The effort of the tractor was reduced thanks to this device from 30 to 40 per cent in relation to the direct dragging on the ground.

c) Two wheeled loading device: is another wheeled accessory which is utilized behind relatively light tractors in order to transport heavy logs. The log is lifted off the ground and because of this the sliding traction effort is replaced by a rolling effort, that is to say divided by twenty or thirty. (In French: Teiqueballe).

d) Trailer with power drive: in order to transport cut up timber, farm trailers were used during many years and it is only in the past few years that we have witnessed the appearance of specifically power drive trailers. They were equipped with a crane, usually hydraulic, permitting the loading of the trailer and generally the wheels of the trailer were rendered power driven to facilitate movement in particularly difficult areas. It was these trailers equipped with cranes and power drive that were the originals of the first "Forwarders" where we replaced the farm tractor with motor elements situated at the front by a regular farm tractor equipped simply with two wheels and reunited to the trailer by a system of jack articulator. The first engine constructed in this manner was the Swedish "Brunet" and "Robur", soon followed by the Canadian "Treever". Presently, the french firm Cemet produces this type of device derived from farm tractors.

(e) Afforestation material: the use of a farm tractor in the forest is not simply limited to harvesting. It can also serve usefully to prepare the soil before afforestation or to maintain afforested zones.

(f) Public works material: we previously sited the ground breaking and levelling devices which are utilized in the forest on the crawler machines and which permits the opening of roadways and maintenance of them, operations which are necessary in connection with the harvesting of virgin or unpenetrated forests.

2.7 The winch

Winches are used in the forest principally on the rear of loading tractors and sometimes on the front in the case of emergency repairs. Actually, an autohauling winch on the front of a tractor would permit it, if it were bogged down in the forest, to be able to extract itself under most circumstances. Besides their utilization on tractors, winches also serve in conjunction with cableways of either one or two cylinders, this equipment permits the transportation of materials for considerable distances.

2.8 Handling machines in the forest

The handling of small timber particularly in the forest has made considerable progress during the past ten years as the result of which the loading worker has been replaced by mechanization, by the use of cranes and in particular hydraulic cranes mounted directly on the loading machine. Reference to these machines has already been made when describing tractors and their trailers.

2.8.1 Forwarders: These were previously referred to when discussing articulated and farm trailers. The device called the forwarder, which is an auto motor engine carrying a crane which permits self-loading and unloading. It is well to mention that crane unloading is often used because it permits the preselection of timber.

2.8.2 Conveyor belts: Instead of using cranes, there has been developed, in the last few years, small conveyor belts which are directly mounted on trailers and permits the workers, when handling timber of small dimensions, such as material for making charcoal or for the paper or board industry, to gather it at ground level, piles and throw it directly on the conveyor belts.

2.8.3 Hydraulic lifter and winch devices: for many years, the most common piece of equipment used for loading trucks was the cable lifter.

2.9 Transport trucks

2.9.1 Description of the different types of existing trucks:

We distinguish the different types of trucks by their number of wheels or number of axels. The multiplication of the carrying axels assists in reducing the unitary pressure on the ground and consequently to increase the load which is to be transported.

2.9.2 Different types of logging trailers: the logging trailer is a type of trailer which operates behind the route trailer in the transport of logs, particularly full length logs. This equipment which operates on one or two axels can be carried empty on the tractor itself.

2.9.3 Braking: It is most essential that the braking system on wood transport vehicles be very firm because when a loaded vehicle must descend long slopes, the normal brakes will heat up and because of this situation will loose their braking power. It is, therefore, necessary at all times that the vehicle be equipped with an emergency brake near the gearbox.

3. Telegheriques

We classify the different utilization techniques of cables in relation to the described below.

3.1 Lost log cables: consist of a cable which is strung between two points so that while one end is on a cliff the other is in a valley. The load of wood which is limited to about ten kilos is fixed to the rope by a wooden hook clipped directly to the billhook. When the load arrives at the base of the valley, the hook jumps and is broken by means of an attachment to the same cable and the load is automatically unhooked.

3.2 Continuous cables: These are made up of one unique cable travelling on pulleys which support it and the loads are hooked, in this case, directly to the cable which plays the role of both the carrying cable and the tractor cable. This type of cable is normally only used for transporting single logs or light loads.

3.3 Go-and-back cable: consists of two parallel cables on which travels two cabin hooks joined by a cord passing on a high pulley and, in order to avoid alternative movements, on another low pulley. This is the system currently used for people to ascend mountains, with a large cabin capacity. This type of device is relatively little used at this time in the forest because it calls for a major installation and it has a very limited output.

3.4 Tre-cable: derived from the preceeding cableways, it is a very common forest model in southern Europe, in particular, called the tre-cablecar. It is made up of two carrying cables, one main cable of a 20 to 25 mm section and one auxiliary cable having a 12 to 16 mm section; these cables are mounted as those of industrial telepherique on poles or supports usually made of wood and are made up of a certain number of cars spaced a calculated distance apart according to the longest span of the cable. The cars are rejoined below on a veritable braking ground which is normally located at the highest station. These cables are chiefly designed for the descent of logs in rough terrain regions

3.5 Cable cranes/Blondin: exist in a variety of forms. The simplest was the one developed by Wyssen in Switzerland which consists of a simple car travelling on a slant and held in place by a cord wound around a winch at the highest station. When one wants the hook to descend the car, it need only stop it, make it do the inverse movement so that it automatically blocks itself on the main cable. At the same time it unhooks a jaw, which frees the hook and it, if there is sufficient counterweight, can descend to ground level where another load can be harnassed. The Blondin model on the other hand, consists of one carrying cable and one simple car is displaced on the cable which is set into motion by a cord which passes by the car, descends by a pulley-block system to the hook and remounts to the car and goes on the return pulley to the other extremity of the cable. This way the car can be displaced all along the carrying cable and it can, therefore, eventually be mounted horizontally. The ascent and descent of the hook is done by a blockage car which is more or less ingenious. The most primitive method consists of having a second cable which displaces the car and allows its mobilization to any point on the carrying cable, whereas the second cord permits the execution of the ascent and descent of the crane hook. Finally, some manufacturers experimented by putting a telecommanded electric or combustion motor in the car itself permitting the ascent or descent of a load from anywhere along the route of the carrying car.

3.6. Cables which use ballons: in rough terrain regions which have a convex profile, such as old mountains (Black Forest, Vosges, etc.) the use of telepheriques is rendered difficult because they normally have a concave form. Also, certain researchers have tried to use the ascent force of the ballons to permit the handling of the above ground load and from this fact permit the transportation over long distances whatever be the profile of the terrain. These materials were especially developed in the Unites States, with some in Russia, but do no seem to have passed the experimental stage.

3.7 Helicopters: we can also include in timber harvesting by cable the method which consists of using helicopters to load the timber. Experiments were done quite a few years ago on the use of machines of exceptional ascending power. Actually, certain military machines can carry loads of up to forty tons, which is largely sufficient for lifting the largest trees in the forest.

4. Other methods for transporting timber

4.1 Floating: The floating of wood is a technique which is still used in the Northern Hemisphere. In fact in these plains regions, the transport of wood by floating is traditionally one of the oldest methods which exists, we site in Norway, for example, the floating association whose beginnings date back to the XII century. The traditional method is called the lost log method; that is to say that during the winter the timber is stocked onto the ice of the lake and when the ice is broken up later and lets the logs continue down the river, they are collected at its mouth where the transformation industry is usually situated. It is this very way that in Canada and also quite often in the Scardinavian countries, the forestry fanchises correspond to the river bassin and the totaility of the timber of the bassin can be dispatched by natural gravity to the paper mill or sawmill in the valley below. When there are many important rivers and canals and when several come into the same bassin, which is frequently the case in Scandinavia, a small metallic plaque or signia permits the wood sorters to orientate the timber towards each utilization sector. This operation is now simplified by veritable sorting centers of which certain ones in Russia are electronic and quasi-automatic and which permit the classification of timber not only by origin but also by quality and utilization.

4.2 Water transport: water transport must not be confused with floating. It consists of transporting timber on light barges in canals which are made for the transport of industrial materials. Likewise there is a similar system existing in Canada and no doubt other countries, where steel barges are used in the transport of timber products and in the case of logs they are of the self-unloading type.

4.3 Railway: private tracks for the transport of timber were very popular in the XIX century and beginning of the XX century, especially in developing countries where a railway may be constructed much cheaper than a road and permits the movement of large tonnage of wood where reasonable terrain conditions exist.

5. Method for calculating cost price of forest jobs

5.1 Calculating the cost price of work material:

In all cost price calcuations, we must consider three types of costs which are:

- fixed costs
- proportional costs
- functional costs.

5.1.1 Fixed costs

1. Depreciation or amortization of material: Year after year a machine will loose its value. It is, therefore, necessary when it becomes unuseable, that the owner be in possession of the required capital to replace the equipment which has become inefficient. It is also important to determine what period of time to redeem the machine. This estimation is very necessary because the hourly cost price of the machine depends largely on the number of hours used annually. The number of hours during which the machine was utilized, is proportional to its productivity and its condition. Usually, this period is determined at the time when repair

costs become greater than the return costs. The simplest method is to consider amortization directly proportional to the time, which is known as the lin ar method. The opposit method is a more rational one which consists of taking each year the actual value of the used equipment on the market, giving us a curve which moves out strongly to the right because it is an exceptional type. In the calculation of cost prices, it is preferable to take the hour as the unit to arrive at an amortized figure, which will be calculated by the buying value less the eventual used value divided by the total number of hours over which the machine is amortized.

It is fitting to remember that for certain machines, such as crawler tractors in particular, it is important, if we want to see the problem more closely, to amortize separately the crawler tracks and the tractor itself; the tracks being used up more quickly than the tractor. The same goes for the tires of large dimension which are used on public works machines. It is advisable to note that, in amortizing machines, it is always necessary to take into account, the age of the machine, because even if it is used very little and still may have a goodly number of usable hours, it is necessary to take into consideration that, at the end of a certain number of years, this machinery may have totally lost its intrinsic value, in spite of the little work it has done.

2. Another item which is desirable to incorporate in fixed costs is the interest (capital required to b a machine, which normally should be included in the remaining value of the capital progressively in accordance with the amortization of the machine. Finally, the insurance, taxes, etc. must be incorporated.

5.1.2 <u>Proportional costs:</u> These costs consist of the maintenance and functional costs. When we refer to vehicles, the maintenance cost of the rolling tracks can be taken separately from that of the vehicle. The maintenance costs of the vehicle itself are those that we are quite familiar with in the operation of an automobile, such as repair of mechanical parts, brakes, clutch, etc. These repairs are also of equally important proportion to the other machines such as the loading machines.

Other maintenance costs are those of accessories which are attached, for example, to the tractor. If on one hand we must proportionally amortize the functioning of the tractor itself, we must also include a section for the cables, loading arches, etc.; that is to say all the accessories that work in conjunction with the tractor.

5.1.3 Functional costs

1. The energy used by a machine during its operation: this energy can either be in the form of motor fuel or electric kilowatts in the case of machines driven by electric motors. In order to calculate the consumption of motor fuel of a tractor we can use a theoretic motor curve, which gives a motor fuel consumption curve. But we must remember that with consumption in g/CVh. we must take minoration coefficient of 40 to 75 per cent, according to the actual efficiency with which the engine preforms. In accessories for fuel motors, we must not overlook the lubricants, grease, all the noramlly used materials which are often proportional costs to those of the fuel motors themselves. The proportion is about 20 per cent and sometimes drops to four to five per cent for tool machines.

2. Salaries: the salaries are those of the people who operates the machines as well as the auxillary services such as the greaser, the workers who are involved in seeing that the equipment functions properly through appropriate scheduling of maintenance and repair.

5.2 Use of cost prices

Theoretic determination of the best mode of work:

Whenever we put into equation form the cost price of each phase of the logging operation that we realize, it is possible to compare them by a graphic or algebra method. In fact, the majority of the cost prices are seen as a first degree equation. This way we can provide an accounting to the origins of the fixed costs and a proportional part which are the proportional costs on which the angular coefficient varies according to their relative importance to the given production. In general we express the cost price according to the production in m^3, according to the parameter, whatever be the loading distance, the thickness of the timber, etc. and accordingly the costs are presented in such form that we can put them into a graphic systems of reference. In comparing a certain number of work methods for a given logging operation, we discover that one method is best from a certain point on while another method becomes more economical from a different point on; consequently, we will find ourselves enclosed by a certain number of curves which finish by encircling the problem, and we can then find the optimum conditions possible to organize a logging operation in order to achieve the best possible economic results. Such a study can, of course, actually be done by computers to which it is necessary to give linear components of each given case. In this fashion we can determine the best theoretic method of work system in a given case.

This analysis can determine the implementation of a network of roads or a telepherique system in a forest mass and allows for the determination in advance of what will be the advantages and/or disadvantages of the two methods from the view point of productivity. It is well to remember, meanwhile, that it is necessary to always keep in mind the social problems that can develop by the use of mechanical materials.

CONCLUSIONS

The choice of material, equipment and harvesting methods to be used for logging operations can be determined, as just indicated by calculation done with the help of computers. But this advanced method should be prepared and analysed by technicians and engineers who are sufficiently qualified and possess the necessary knowledge in order to be able to recommend the best methods and machines, as well as being capable of analysing the social and psychological conditions of the population affected by their projections.

In effect, the human problems while not being considered in the calculations must neverthelessbe relied upon to contribute to the success or failure of a project, consequently it is most necessary that common sense and good judgement prevails at all times, especially in the area of management-employee relations.

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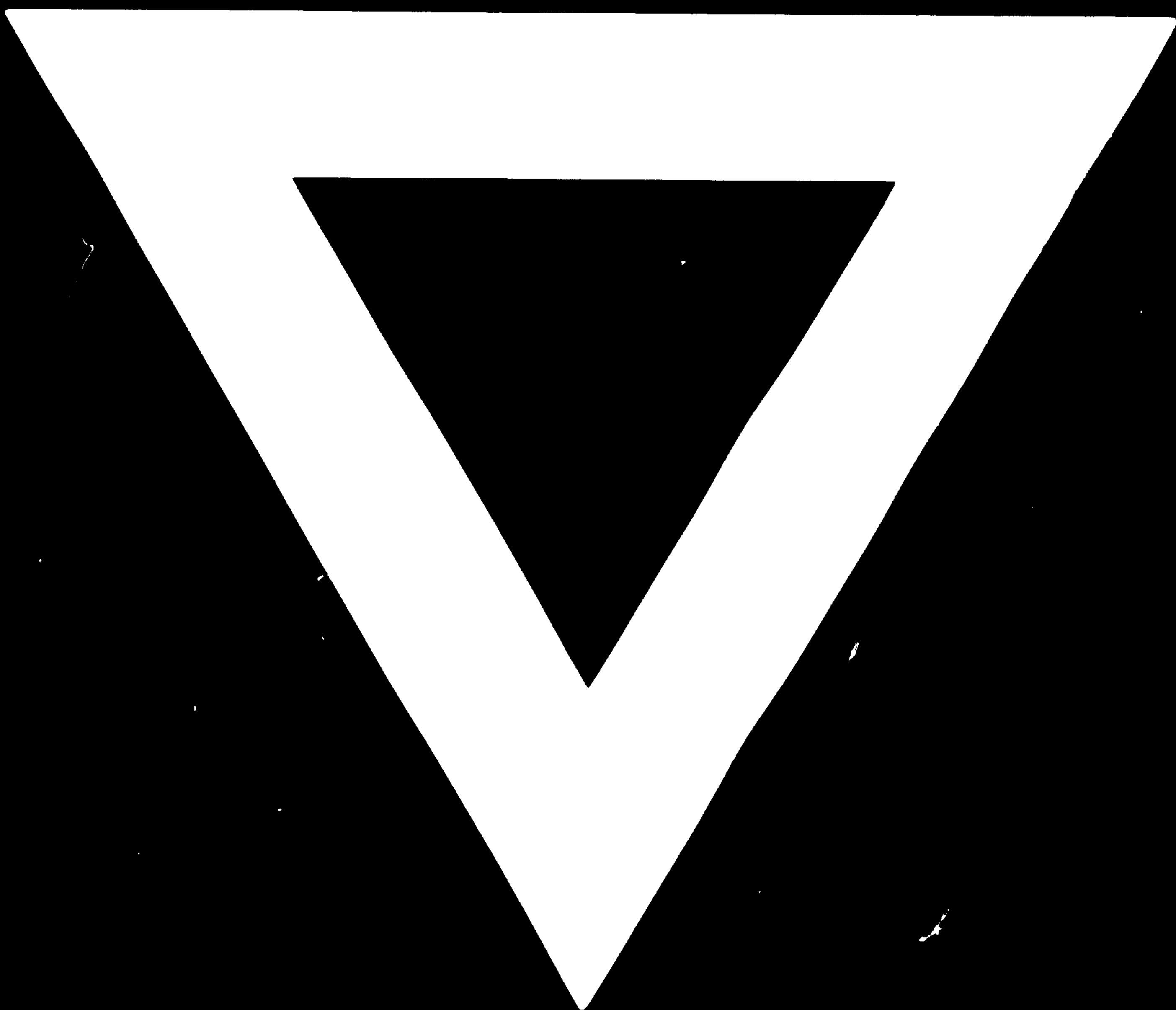

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SELECTION OF FORESTRY EQUIPMENT*

by

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1. Introduction

The definition of logging refers to the selecting of trees in the forests, felling, limbing, bucking, skidding, decking and then loading them in log lengths on to trucks or railroad cars for transport to a market or processing area. In other words it represents the extraction of a raw product from the forest. It is true that there exists in this operation a number of successive functions all of which require the need for a rather tough or rustic type of man-power which is agreeable to living under rather crude conditions and which invariably are located somewhere in far flung areas of the forest wilderness. Nevertheless, it is becoming more and more a civilised occupation as due to continued pressure from government bodies the forests throughout the world are being better controlled and managed while the timber is being selected and extracted as for instance, industry is now required to lay out and construct their logging roads so that eventually these roadways will either tie in with or form part of the national road system of a country.

Whereas only a few years ago the job of a lumberjack was considered a difficult, dangerous and low paying one, for some time now a steady move towards the complete mechanisation of forestry operations has made it so that there is a trend towards the utilization of more and more specialised manpower and consequently towards a more and more elevated standard of living. This situation can be considered as a step forward because in a business that was once considered as being unthinkable to be involved in, the logging business and that of the logger have become more and more attractive to the younger generation and society in general.

1.1 Different phases of logging

Definition: We call a phase any operation which consists of executing a job without the need of changing tools; for example, the felling of a tree encompasses a first phase: the actual job of felling is done by using a power saw and once the tree is felled, the operation of limbing, requiring the use of a manual tool or lighter power saw, is considered a different phase from the first one. Bunching the timber is the third phase and skidding is the fourth. The stacking of the logs and the bunching of timber in order to execute this operation is an auxilliary phase. After the skidding, the logs are stacked along the roadside. It is the stopping point in the forestry operations; on the other hand, the loading of the logs onto the trucks is considered a phase and afterwards the hauling of the logs another phase; the unloading at the arrival point is normally the final phase unless the material is to be subject to further transport by other means such as railway or barge.

1.2 Operational analysis of time distribution

The different phases, as they have just been described above, were the object, by many specialized institutions, of systematic studies of their respective time. Without going into detail on these studies, we can assume that the felling operation represents only a small percentage of the total logging time, whereas the burning of small limbs and branches (slash), could represent up to fifteen per cent of this total time.

To this analysis it is in order to apply a cost coefficient which depends on the material used during each given phase. For example, the felling operation with a power saw costs the salary of the worker who executes the job plus the reasonable amortization of the machine and its hourly utilization cost, that is its hourly consumption of fuel oil and the cost of required maintenance per hour of operation.

When we refer to the skidding operation, the unit cost per work hour is evidently much higher, because, in addition to the salary of the operator and possibly an assistant, it is advisable to take into account the amortisation of the skidder plus its operating cost, which of course can be up to ten or twenty times the cost of the operators salary.

In taking each phase, by multiplying the time spent for a given operation by the hourly cost of each technical process used, we can determine the total cost of the operation from the forest to the mill. Furthermore, a comparison of the different phases can be done by linear programming or better yet by computer.

The conclusion of such an analysis permits the planner to determine the best method to employ in order to exploit a given forest area. But, in addition to these theoretic calculations, it is necessary to take into account the restraints which encompass the problem of logging which generally result from the technology used for the proposed job.

1.3 Definition of restraints

There are four types of restraints: physical, silvicultural and economic in addition to which it is advisable not to neglect the psychological aspect.

1.3.1 The physical conditions

(1) The general lay-out of the region:

a) **Mountains:** In mountaineous regions, the slope of the terrain is the determining factor in the choice of equipment to be used. For slopes under 20 - 25 per cent, it is not feasible to utilize auto-propelled vehicles which manouver on the ground, however, crawlers tractor can work on 30 and even 35 per cent slopes. Wheel skidders should normally not be used for slopes above 20 per cent in order not to risk the rupture of stability. In the case where we have to work on higher slopes, we would naturally resort to the utilization of cable systems or telephericues, assisted somewhat by baloons or helicopters. In the case where we use automotive vehicles, the slope dictates the choice of the vehicle by the determination of its center of gravity, in addition to which the power required to make the vehicle climb the slope will often be a determining criteria for the choice of an engine. It is in fact essential in a rough terrain region that the tractor, without cargo be able to climb the slopes at an appropriate speed and careful adherance to conditions. We would naturally try to use gravity for skidding the loads and as often as possible would try to organize the areas in such a fashion that the machines move in the direction of the slope rather than climb them. However, it is interesting to observe that in the case of utilization of cable systems, or in particular cable-cranes, it is easier to work in ascending the loads rather than trying to descend them, because in the case of pulling the logs towards the top, they have a tendancy of being pulled from the soil, whereas in the inverse they slip and risk floundering in the soil. It is also advisable to think about the altitude as engines have an inferior effeciency to that which they have at sea level because of the rarefication of oxygen in the air. The loss of power which is ten to fifteen per cent between 800 and 1500 meters reaches [illegible] per cent when the engines are at an altitude of 3000 meters above sea level.

b) Plains: When we find ourselves in conditions of exploitation on relatively flat terrain and where the problems of slope are no longer preponderant, it is the state of the soil which becomes the determining element for the choice of transport vehicles. In fact, if on dry terrain the problems of adherence are of minor importance, as soon as we encounter marshy terrain, very humid or staying humid most of the year, these problems are so important that in certain cases, the technicians prefer to utilize traction cables at ground level in preference to vehicles which are invariably amphibious. By the same token, in regions such as in the southern United States, or tropical regions, the railway was for a long time the most rational mode of penetration, costing in fact less than the established routes and having a particular character that well served the early exploitation of the forests.

Finally it is advisable to note the particular cases of artificial plantation of trees in rows which requires, when we want to preserve the reserved trees, a material specially adaptable as a replacement for this method of exploitation.

2. The climate

The first criteria on the subject of climate is the variation of temperature. It is necessary to remember, as was for the altitude, that according to the temperature of the surrounding air, the efficiency of a motor varies in great proportions, due to the rarefication of oxygen in the warm air. This is estimated to be between 30 and 50°C, while there is a variation of about 25 per cent in the efficiency of a motor. In addition, it is often overlooked that the climate has a greater influence on the state of the soil which is in direct relation to the changing climatic conditions. In cold regions such as Siberia, the Scandinavian countries or Northern Canada, snow becomes an aide in exploiting the timber because it permits the forming of routes on compressed or even frozen snow on which we can either directly haul the loads or use a sled. Actually considerable quantities of timber can be moved with an excessively weak coefficient of friction under these conditions. In temperate climates this approach is not applicable as the condition of the climate slows up work during the rainy period but aboveall transforms the soil, which usually has a sufficient holding ability, into a particularly unsuitable ground for the transport or travel of vehicles and reduces, because of this fact, the period of time when exploitation, or rather the skidding of wood, is profitable. A similar observation can be made for the countries in a tropical climate region, because in fact, in these regions the rainy season forbids, generally for a long period of time, the penetration of the forest by mechanical means, resulting in the maximum usage of transport throughout the dry season when the holding ability of the soil permits the passage of heavy equipment. Finally, one last point pertains to the climatic conditions in the wind factor. In fact, this last factor can be in certain rough terrain regions or along the sea, a preponderant element to the prohibition or slow-up of the exploitation of the timber. Therefore, the forest operations planner should, in all instances, take into account the presence of the wind factor when he schedules cuttings and in particular clear cuttings, in order to avoid that by unexpected wind storms the area does not suffer unnecessary timber damage due to excessive material having been blown down.

3. The soil

Forest soil is generally formed from the decomposition of leaves of needles whioh forms a more or less thick humus layer that lies directly on the mother rock, whereas in agriculture soil the surface contains a layer of cultivated plant roots which form an excellent support for the adherance of the transport machines. In other words, the forest soil is a surface cluttered with destroyed vegetation which makes the real conditions of the under soil, and if the operator does not have a fair knowledge and a certain amount of experience with driving on this type of soil, he can quite easily encounter some problems when moving his machine over the area. The following is a definition of the different types of forest soil according to their mother rock.

a) Clay soil: this is a particularly resistent soil when it ie dry with a very high holding ability but on the other hand becomes very slippery when saturated with water and ite holding power often diminishes quite euddenly. It ie, therefore, necessary with such soil to plan the harvesting of timber during the dry season, although emergencies do arise to work during the rainy season. In the latter case, it is necessary to anticipate the need for equipment which will permit the vehicles to pase over the weak places. The moet suitable forestry artifice is the auto-hauling winch which is attached to the front of the vehicle.