A Comparison of Over Snow Vehicles Produced at Utah State Agricultural College

Ross W. Eskelson

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A COMPARISON OF OVER-SNOW VEHICLES PRODUCED
AT UTAH STATE AGRICULTURAL COLLEGE
by
Ross W. Eskelson

A thesis submitted in partial fulfillment
of the requirements for the degree

of
MASTER OF SCIENCE

in
Industrial Education

UTAH STATE AGRICULTURAL COLLEGE
Logan, Utah
1955
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Ross W. Eskelson
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The need of the study

Travel over snow by vehicle in Arctic and mountainous terrain is one of the most difficult problems of our Armed Forces and other public and private agencies. Agencies whose services demand over-snow travel find little or no adequate means of transport. Those vehicles which are available, are either economically infeasible in construction and operating costs, or have serious operational limitations.

A great amount of research has been done, but as yet, no vehicle has been produced to successfully meet the varied problems of over-snow transportation.

The Utah State Agricultural College, and its affiliated organization, the Utah Scientific Research Foundation, in cooperation with other public and private agencies, has sponsored several research projects which have attempted to produce a satisfactory over-snow vehicle.

There is need to coordinate the conclusions of these research projects and to make a comparative analysis of the vehicles produced. This analysis will aid further investigation in the field, and help prevent duplication of effort in areas previously investigated.

The specific objectives of this study may be stated as follows:

1. To compile a historical project record of over-snow vehicle research done at Utah State Agricultural College from 1939 to 1954 including pertinent technical data.

2. To make a comparative analysis of the vehicles produced by these research projects.
3. To relate what has been done in the field of over-snow transport at Utah State Agricultural College with that done by other selected agencies during the same period.

Completion of these objectives should be of value to future designers of over-snow vehicles by more accurately describing the operational problems of these machines in the many varied conditions in which they must operate to be successful.

Procedures in making the study

The historical information has been assembled from field diaries of project leaders, periodic reports of agencies concerned and from personal interviews with the various project leaders during the period of vehicle development.

The comparative data have been assembled in the form of a descriptive analysis of the important performance and design features of each vehicle. Comparative charts will be made where field trials have been held for the purpose of making a performance analysis.

Where possible, photographs have been used to supplement the descriptive machine data.
BACKGROUND

The over-snow vehicle projects at Utah State Agricultural College are the result of the snow survey and water run-off forecasting program.

The science of snow measurements for the accurate forecasting of water run-off was initiated by Dr. J. E. Church of the University of Nevada in 1905 when he began his experimental work. It is of interest to note that Dr. Church was a professor of Latin, German, and Art Appreciation. He became interested in the science of snow measurement because of his love of the outdoor life. He has studied snow in nearly all sections of the world, and is probably the outstanding cryologist alive. His work has resulted in the vast network of snow survey courses.

In 1923, Utah established its own snow measurement system. This program was pioneered under the direction of George D. Clyde, former Dean of Engineering at Utah State Agricultural College. Clyde continued the snow measurement work, initiated by Dr. Church, and it was under Clyde's direction that the snow survey program became the exact science it is today.

In 1935, the federal government began its support of the snow survey program, resulting in the present large network of snow survey courses throughout the country. During the period from 1923 to 1940, eighty-three snow survey courses were established in Utah. Most of these courses were located and laid out personally by Clyde. The initial layout and periodic checking of these courses was all done on snow shoes. This, as anyone who has used snow shoes can attest, was a monumental task.
During the later years of the above period, the agriculture and business people began to depend more and more on the accuracy of the snow survey and water run-off forecasts. This resulted in a demand for more frequent and more extensive snow surveys. At this time, it became apparent that it was no longer feasible to adequately cover the snow survey system in Utah with only snowshoe transportation. The timing of the surveys was too exacting, and the dangers to the snow surveyors from over-exertion and exposure had become greater as the system expanded. As a result of the above factors, Clyde decided to obtain some type of vehicle which would replace the snow shoe as a means of over-snow transportation.

The commercially available over-snow vehicles were considered, and upon examination, it was quite evident that none of them was suitable for the mountainous regions of Utah. The mountains of this area present a wide variety of snow conditions and an extremely versatile machine is required to successfully traverse all the different types of snow and terrain. The only practical solution was to attempt to produce locally a vehicle suited to the use of snow survey crews in the area and climatic conditions in which they must operate. This decision was the first step in the extensive research program in over-snow vehicles at the Utah State Agricultural College.
Hansen Snowmobile No. 1

The snowmobiles produced by Walter Hansen of Ephraim, Utah, while not constructed at Utah State Agricultural College, are included in this paper because of the direct influence they have had on the designs of all the snowmobiles produced since at Utah State Agricultural College.

Hansen built at least two snowmobiles previous to his employment at Utah State Agricultural College. These two machines were constructed by Hansen on his own time and money as an avocation. It was intended that they be used to transport skiers to the top of Mt. Horseshoe, near Ephraim, Utah. These machines were built with an open centered self cleaning track, and a front steering ski or toboggan. These features have since been used on most snowmobiles produced at Utah State Agricultural College. Hansen obtained a patent on this open centered type of track. The patent is titled "Open Centered Snow Tracks" No. 2385758, issued October 8, 1943.

The first machine produced by Hansen featured a 1929, six-cylinder Chevrolet engine. The transmission and differential were from a Chevrolet 1½ ton truck, which gave the snowmobile ample gear reduction, although most running would necessarily have to be done in the lower gears with these units. Top speed on good snow was twenty-five miles per hour. Steering was accomplished by means of a large single toboggan attached to and running in front of the snowmobile. This toboggan was also used to carry additional equipment and personnel. This arrangement has since proved to be relatively ineffective as a means of steering and was one of the features Hansen changed on his second machine.
The tracks were open centered, all metal type, running over pneumatic tires. (Figure 2.) Flexibility of the tracks was obtained by hinge pins spaced approximately twelve inches apart along the track length. These metal tracks were later replaced with rubber belting tracks to provide longer life and fewer maintenance problems.

Hansen Snowmobile No. 2

The second machine was, in many features, similar to the first snowmobile produced by Hansen. The engine was changed from a Chevrolet to a Ford V-8, giving the advantage of more power and the desirable feature of a full pressure lubrication system. This full pressure lubrication system would work while tilted twenty-five degrees in any direction. The lack of a full pressure lubrication system is a serious drawback to any engine for use in snowmobiles. This feature has been changed in more recent Chevrolet engines and since 1953, these engines are equipped with a full pressure lubrication system.

The transmission and differential used was, as in the first model, from a 1 1/2 ton truck with the same problems of low gear running and heavy weight. The track drive was by pneumatic tires featuring a knobby tread to improve the frictional coefficient between the wheels and the track. Both of Hansen’s machines drove the tracks from the rear end only.

An attempt was made to improve the steering characteristics of this machine by use of two widely spaced skis instead of a single toboggan-type runner. (Figure 1.) This system was undoubtedly more effective under sidehill conditions. Two separate skis, or even one single ski, seemed to have definite advantages over the wide toboggan-type ski. The toboggan-type ski had so much frontal area that it required
Fig. 2. Hansen Model 1 Snowmobile and designer Walter Hansen.
excessive amount of power to push it through the snow. This was especially true in soft snow or powdered snow conditions.

Both of Hansen's snowmobiles were perhaps crudely put together, but this does not necessarily reflect upon the skill of the builder, but rather upon the limited materials, tools, and finances he had to work with. Most of the track features, and some of the other features, have been retained in all subsequent snowmobiles that have been produced at Utah State Agricultural College.
CHAPITR II
THE UTAH SNOWMOBILE

Utah Snowmobile No. 1

During the year 1941, it became very evident that something had to be done to provide better transportation for the snow surveyors. Dean Clyde subsequently contacted Hansen at Ephraim to acquaint himself with the features of the Hansen snowmobile. Having received Hansen's recommendations as to what was to be desired in constructing a snowmobile, Clyde initiated a construction program for a new snowmobile at the college in Logan, Utah.

Hansen did not come to Logan at that date. The work was initiated and parts accumulated under the direction of Messrs. Clyde Hurst, Oliver Lucherini, and Roy France, employees of the automotive department of Utah State Agricultural College. Hurst, Lucherini, and France, working from instructions relayed from Hansen at Ephraim, had begun construction of the snowmobile when Hansen arrived in Logan. Upon his arrival Hansen recommended changing the method of tightening the tracks. The method used was to support the front axle only at the center and allow it some free pivoting action so as to equalize the pressure upon the tracks. Subsequent designs in later snowmobiles have since proved this to be an unfavorable method of track adjustment.

A second change recommended by Hansen was the mounting of the center idler wheel on springs so as to depress it below the level of the front and rear wheel. This change was made to improve the steering characteristics of the vehicle. The sprung center idler wheel did help the steering characteristics on hard ground and crusted snow. However, it was a definite hindrance on soft snow, as it tended to
concentrate the pressure at a single point. This concentration of pressure is in direct opposition to the information now available, which indicates the weight should be spread uniformly over as large an area as possible.

The Utah Snowmobile No. 1 was completed in time for the 1940-41 snow-survey season, and put in operation by the Utah State Agricultural College Engineering Experiment Station. This machine proved to be far too large and heavy for desirable operation in soft snow. However, it did operate for several winters as it was the best machine available at that time.

The flotation characteristics of this vehicle, that is pounds per square inch of track area, were not desirable, and while its actual weight is not known, it is estimated by the author to have been at least 1 1/2 pounds per square inch of track.

The machine steered by a single, ten inch wide, six foot long, metal ski. The ski was mounted at the end of a ten foot long boom. Motion was transferred from the steering wheel to the ski by means of a sprocket, chain, and cable arrangement. (Figure 3.) The mounting of the sprocket was such that it did not pivot at exactly the same point as the boom, and as the ski rose and fell while passing over obstructions, a binding effect was produced upon the steering cables, making steering difficult and sometimes impossible.

The tracks were all metal of the hinge pin type, with grousers placed both crosswise and lengthwise of the tracks. The tracks had good climbing and sidehilling ability, but there was a definite tendency of the tires to spin in the tracks. Several methods to correct this spinning were tried, the best being the use of knobby cleated tires and cutting cross grooves so that the tires were engaged in somewhat of a
Fig. 3. Utah Snowmobile Model 1
The all metal tracks had a short life. The hinge pins and the connecting holes at the end of the track segments tended to work-harden, becoming brittle and then break.

During the last winter this machine was run, it sometimes became necessary to carry along an acetylene welding outfit to make field repairs when the tracks broke. The tracks were also extremely difficult to manage when it became necessary to remove and replace them, making any type of field repairs to the machine difficult.

This machine was equipped with a 1929 Chevrolet six-cylinder engine of approximately seventy horsepower. The transmission was a four-speed unit. The differential was from a 1½ ton Chevrolet truck. The transmission and differential were both very heavy, contributing to an undesirable overall weight.

The machine, running with normal truck gearing, was forced to operate in the first or second gear most of the time. A better arrangement would have been to reduce the final drive ratio by at least two to one so as to provide operation in the upper range of the transmission the majority of the time. The engine also had serious lubrication difficulties as on Hansen's previous machines. The Chevrolet engine had very good torque characteristics, especially in the low speed range. This feature is desirable in any snowmobile as much of the running is done under full or nearly full power. This high torque type of engine will lug down much better than some other engines which have high engine speeds.

Utah Snowmobile No. 1 (modified)

The original Utah snowmobile first ran during the winter of 1941-42. It continued operation in its original design through the winter of 1944-45. During the winter of 1945-46, the tracks of the No. 1 machine were modified.
The metal tracks were discarded and were replaced with a rubber track constructed from conveyor-type belting. The grousers were constructed from half-inch water pipe and a channel was formed in the middle of them in a semi-circular shape, in which the tires ran. This type of grouser tire guide arrangement proved unsatisfactory. The machine could hardly operate in any type of snow due to slippage between the wheels and the tire guides. An attempt was made to improve the friction between the wheel and tire guide by cutting cross grooves in the tires but this proved to be of little value.

In the spring of 1946, France and a snow survey crew took this machine on a trip to Monte Cristo, east of Ogden, Utah, but they were unable to reach their goal because of serious wheel slippage. They had to return without making the snow surveys. This was the last trip attempted by this machine. After its return to Logan it was dismantled in the summer of 1946.

The No. 1 Utah Snowmobile, and the modified machine, while not completely successful as over-snow vehicles, did provide a large background of information and experience which could be used in constructing later vehicles.
CHAPTER III

BARRETT SNOWMOBILES

Barrett Snowmobile No. 1

The year 1946 started a new era in snowmobile construction at Utah State Agricultural College. Clyde had resigned his position as Dean of the School of Engineering and Director of the Engineering Experiment Station, to accept a position as Chief of the Division of Irrigation of the Soil Conservation Service, having direct charge of all irrigation research work in seventeen western states. Upon assuming his new position, Clyde immediately took steps to initiate a program of research and development of over-snow vehicles to facilitate the broad snow survey system now under his direct charge.

It is noted here that it was the continued interest and driving force of Clyde which was responsible for the snowmobile development program during the period from 1940 to 1953, at which time Clyde left the employee of the Soil Conservation Service. Clyde is now director of the Utah Water and Power Board, and Commissioner of Interstate Streams for the state of Utah, and at present is directly concerned with the development of the Upper Colorado River Irrigation Projects.

During the summer of 1946, Mr. Willis Barrett, an engineer with the Department of Agriculture, returned from an assignment in China. Upon assuming his duties with the Division of Irrigation, Barrett was assigned by Clyde to head up the research in over-snow vehicles at Utah State Agricultural College. Barrett reviewed what had been done in previous years and on previous machines, and then directed his attentions, and some experimentation, to the reaction of snow under compressive forces.
It was Barrett's feeling that most attempts to meet the over-snow vehicle problem had been done by adapting automotive vehicles or variations thereof to over-snow transportation, which was akin to adding wings to an automobile and expecting it to fly.

He began a series of tests to determine the effect of weight per unit area on the various types of snow, and the force necessary to pull sliding loads, and loads on rollers over different kinds of snow. He made definite attempts to measure the rolling resistance of different types of tracks and wheels in different snow conditions.

Outstanding among his investigations was his attempt to determine just what pattern snow took under compression from different loads. This study was done by fixing a grid of colored lines in the snow, inserting tubes with colored antifreeze solutions into the snow and then withdrawing a swab which left lines in the snow. These grid lines were placed both vertically and horizontally. Weights were then dropped on the grid area. When the weight was removed, the snow was carefully scraped away to the plain of the grid. It was then possible to examine the distortion of the grid lines and obtain a true picture of how snow distorts under a compressive load. The author assisted Barrett in making these tests, and it is his belief that this was one of the most worth-while investigations undertaken. More work needs to be done in this field and it is quite evident that it is this type of investigation that will yield valuable information for any future designers of snowmobiles.

Before starting construction of the first machine built under his direction, Barrett noted several features, as a result of the above tests, which he felt should be incorporated in a snowmobile.

A machine should be as light as possible, not to exceed six-tenths of
of a pound per square inch of supporting area. The tracks should be of such a type as to provide the widest distribution of load, with no localizing pressure points which tend to break through the supporting snow surface. A device should be incorporated by means of springs, levers, or a combination of both, to provide some means of shifting the center of gravity of the snowmobile in negotiating different slopes. That is, the steeper the slope the more forward should be the center of gravity. The steering should be done by means of some ski arrangement with only enough weight on the ski to provide adequate steering and to do some initial packing of the snow ahead of the tracks. This packing of the snow by the ski improves the track flotation.

Due to the lack of accurate field diary information, the figures which follow on Barrett's No. 1 machine are only close approximations. A good view of general construction details can be had from Figure 4.

The machine weighed approximately 1,800 pounds and had a flotation characteristic of seven-tenths of a pound per square inch. The tracks were of the metal type with hinge pins. The track sections were approximately eight inches long. They were constructed of light sixteen-gauge stainless steel sheet. Difficulty was found in preventing them from work-hardening and failure from metal fatigue.

The machine had a bogie wheel system of three small wheels which helped to distribute the load evenly over the track area. These small wheels had such a small rolling radius and were equipped with such poor bearings, that they would not stand the loads imposed upon them. Tire and bearing failure was frequent.

The track was originally driven from the rear wheels only by means of friction, and later by means of a sprocket-tooth arrangement, cut in the thick rubber surfaces of the driving wheels. It is noted here
Fig. 4. Barrett Snowmobile Number 1 - designer Willis Barrett standing on machine
that the sprocket arrangement of driving a track is generally unsatis-
factory due to the difficulty of maintaining a constant pitch line
distance on the track and driving wheel. The track either attempts to
climb ahead or lag behind the driving wheel causing a jerky uneven motion
which produces severe vibrations and consequent failure of the vehicle
components.

The engine used in this vehicle was a Ford V-8, sixty horsepower
unit. This engine was reliable and had one of the best power weight
ratios of any engine that has been used in snowmobiles produced at Utah
State Agricultural College. It is unfortunate that the production of
this engine has since ceased because of popular demand for a more power-
ful automobile.

The transmission used in this vehicle was from a Model-A Ford, as
was the differential assembly. The width of the differential was cut
down to give a narrower tread to the snow vehicle. It will be noted
here that these units were probably not Barrett's choice as the most
desirable, but rather the only ones available due to limited financial
resources and the limited availability of power units of any type so
soon after World War II.

Steering was done by a single broad toboggan type ski. While this
type ski had some advantages in tending to pack the snow down slightly
ahead of the tracks which reduced the necessary clearance of the vehicle,
it was not a very effective method of steering and was of no value when
crossing intermittent stretches of bare ground. The wide ski had to
be removed and small steering wheels installed in its place for any bare
ground encountered.

The machine had a top speed of fifteen to eighteen miles per hour
and normally operated at ten to twelve miles per hour. The climbing
and sidehilling characteristics were both good. It was able to negotiate a slope of thirty per-cent while climbing or sidehilling.

This machine saw limited use on snow surveys during the winter of 1946-47. It was plagued with failure of one part of another all season. The metal tracks in particular gave trouble as did the small bogie wheel system.

**United States Geological Survey Machine No. 1**

During the summer of 1946, United States Geological Survey also became interested in procuring a snowmobile for use in their stream gauging work during early spring operations in high mountain areas.

Mr. W. V. Iorns, project engineer of the Logan office of United States Geological Survey, contacted Clyde, and it was decided that an additional machine should be constructed at the College under the direction of Barrett.

Barrett was aided in the construction of this vehicle by Emmett Devine and other student help. The machine constructed for United States Geological Survey was similar to the No. 1 Barrett machine except that it was smaller and lighter. The power was provided by a Crosley four-cylinder engine of twenty-six horsepower. The transmission was a combination of Ford and Crosley transmissions placed in tandem providing a compound gearing arrangement. The differential was from a Crosley. The brake drum were replaced with sprocket and the final drive to the rear wheels being by a chain from the sprocket on the differential to the rear wheels.

This machine showed definite promise as it was extremely light making it possible to negotiate very soft snows. It was plagued by many mechanical failures, chief among them being trouble with the small high speed Crosley engine. This engine was a sheet steel, welded type
block assembly which distorted readily under varying hot and cold motor conditions causing subsequent failures among the valves and other internal parts. On later models, this engine was replaced with a Crosley engine which had a cast-iron block which partially alleviated this problem. The Crosley transmission also gave trouble because the counter shaft ran in bronze bushing, rather than ball or roller bearing. These bronze bushings wore rapidly producing excessive gear clearance and subsequent failure of the transmission unit.

The method used in this machine of running two automotive transmissions in tandem is definitely not good. The second unit in the power train is very much overloaded in that the torque has already been multiplied several times before entering the rear transmission. This means, the bearing and gears of the rear transmission must carry several times their designed load, and it usually fails before being in operation very long.

The final drive from the transmission to rear wheels by means of roller chain was also a source of considerable trouble. These chains were not enclosed in any type cover and the snow and ice would build up in between the sprocket and chain until it would ultimately exert enough pressure to break the chains. This type of open drive has been tried on several other snowmobiles and has failed in all cases.

When roller chains are used as a means of final or primary drive in over-snow vehicles, they should be enclosed in some suitable case, one that has constant bath lubrication.

The small Crosley machine would, under most conditions, climb exceedingly steep hills. During operation on one trip through the Uintah Mountains of Utah, it negotiated several slopes of approximately fifty-five to sixty per-cent.
It was the first machine to ever successfully negotiate the slopes leading up to the Washington Lake Snow Course. This particular run, in the author's opinion, provides the ultimate test of any snowmobile for use in the western mountains. Only one other snowmobile has ever successfully climbed to this snow course, that being one of the earlier models of the Frandee SnoShu, a machine described later in this study.

**Barrett Snowmobile No. 2**

During the summer and fall of 1947, Barrett undertook the redesign and modification of his Number One machine. This machine had been used during the past season by Soil Conservation Service for making snow surveys in northern Utah. The machine was operated during most of this period by Dean K. Fuhriman, a snow survey project leader for Utah.

Barrett had continued his experiments on the compressibility of snow during the winter of 1946-47 and he proceeded to incorporate several changes in his vehicle which he believed would be desirable. The same motor was used, but an additional transmission was installed behind the first transmission to make it possible for the vehicle to have an extremely low gear ratio. This extremely slow speed is very desirable in many situations. However, this method of achieving low speed by two transmissions in tandem, is definitely not good.

The tracks were changed from the all metal type to an open-centered rubber conveyor belt type with grousers made of light chrome molybdenum steel tubing. Short projecting lengths of tubing were welded to the grousers at right angles to improve the machine's sidehilling ability. Improvements were made to the bogie wheels to improve their bearing life.

The center wide toboggan type steering ski was replaced, and in
Fig. 5. Barrett Snowmobile Number 2
its place was substituted two narrow skis of approximately six inches width and five feet length. These skis were so placed primarily to pack the snow directly ahead of the tracks.

The skis had adjustable fins on each side which could be lowered by means of an adjustment to aid in turning of the machine in hard surface snows. The skis also had box-type construction so as to present some edge area to the snow to aid in turning.

This double ski arrangement was a very definite improvement over the wide single toboggan. It was also now possible to place two retractable pneumatic wheels of approximately twelve inches in diameter between the two skis which could be lowered to negotiate intermittent stretches of dry ground. This vehicle as in its previous form, also included a spring arrangement which provided for a limited oscillation of the whole track assembly helped to smooth out the ride and distribute the load under uneven snow conditions.

The machine, in its redesigned form, operated during the winter of 1947-48. As long as this machine could be kept free from mechanical failures it did a good job of successfully negotiating most snow conditions. However, it was continually plagued with mechanical trouble.

It is the opinion of the author that the general over-all design of this vehicle was such that it could be called a successful snowmobile. The author believes the aforementioned mechanical failures were the result of general poor workmanship.

Weld failures were frequent as were material failures. Most of these failures were due to improper choice of welding methods, material choice, etc. One should recognize that Barrett and his associates were working with very limited resources and the period immediately following World War II made it difficult to obtain a choice of wheels,
bearings, and other structural components of the vehicle.

The author attributes most of the weld failures on the vehicle to the electric arc welding method which was used on thin materials, particularly those of chrome molybdenum steel. A better method would be to follow the recognized aircraft industry practice of using the oxy-acetylene method of welding chrome molybdenum steels, which give sounder welds and less locked-in stresses which lead to subsequent failure from fatigue.

United States Geological Survey Snowmobile No. 1 (modified)

While Barrett's No. 1 snowmobile was being modified, the United States Geological Survey machine was also brought into the shops at Logan for rework and overhaul before the coming snow season of 1948-49.

The transmission bushings were replaced in the small Crosley transmission and an attempt made to have the factory build a transmission for this vehicle with roller bearings on the counter shaft. They were not successful in their efforts to procure this type transmission.

Later in the season, the engine exhaust system was directed against the chains and sprockets. This was successful on in moderate temperature conditions. In extremely cold weather this exhaust system aggravated the icing conditions as it melted some of the dry snow to produce ice. Later the sprockets were ground on the edges at the root of the spaces between the teeth to narrow the contact area between the sprocket and the chain. This increased the load between the sprocket and the chain per unit area, to an amount that would squeeze out the ice and partially eliminate the icing conditions. This shortened the life of the sprocket and chain.

This method was the final attempt by Barrett and his associates to drive an over-snow vehicle with an open chain drive. It was concluded
Fig. 6. United States Geological Survey Snowmobile Number 1 with modified tracks - Barrett. Snowmobile Number 3 on right
that it was impractical to successfully meet this chain icing condition. All chains on later machines were run in closed cases.

On a later modification of this vehicle the chains were run in closed cases and the exhaust was introduced into these cases to eliminate any water which leaked in. This application of the heat again gave the opposite of the desired result and only produced worse icing conditions. It was concluded that the best solution was an oil bath closed chain drive.

Barrett Snowmobile No. 3

In the summer of 1948, the Division of Irrigation of Soil Conservation Service under Clyde, decided it should launch a new effort in the study of the over-snow vehicle transportation problem. Arrangements were made to construct one totally new vehicle for the Logan office of Soil Conservation Service, and to modify further the machine of United States Geological Survey. Barrett again was to have charge of the design of these two vehicles and a better arrangement as to working facilities and materials procurement was to be provided. In June of 1948, the author was hired to assist Barrett in constructing this new machine and a few weeks later two students were also hired.

The Barrett snowmobile, it was decided, should be constructed first and the modifications would come later on the United States Geological Survey machine. Before starting the actual construction of the No. 3 Barrett machine, considerable preliminary design and layout work was done. This was really the first time that any serious engineering design work had been done prior to construction on the snowmobiles at Utah State Agricultural College. The previous machines had been put together with the design work accompanying the construction. This, of course, led to many difficulties.
The tracks were changed considerably on this vehicle. The belting used was molded rubber belting joined by vulcanizing to form an endless belt rather than using belt fasteners. The grousers were triangular section folded from sixteen-gauge chrome-molybdenum steel. Small projections were welded to the grousers at right angles to improve side-hilling characteristics, and also to provide a practically continuous surface for the small bogie wheels to run on.

A system of nine bogie wheels was provided with the bogie wheels being cast and turned from aluminum with a three-eighths inch thick layer of rubber vulcanized to the aluminum to provide a running surface against the track. This bogie wheel system provided an excellent distribution of the weight, but the small rolling radius and the rigid mounting of the solid bogie wheels, made them very vulnerable to shock from rocks and other obstructions in the snow. The rear drive wheel was also constructed with a cast aluminum rim with rubber vulcanized onto the driving surface. It had an extended center section to aid in keeping the tracks on.

First attempts were made to drive the tracks by friction. The first trial run of this machine proved this method of drive to be in vain, and blocks were added to the wheels to form a sprocket effect which prevented most of the track slippage. The front or tightening wheel of the track, was also of the cast aluminum vulcanized rubber construction, and it was provided with a flexible mounting which included a spring for the purpose of maintaining a specific fixed tension on the tracks at all times. This spring arrangement was not satisfactory as the rear driving wheel tended to stretch and suck the front wheel toward the rear causing the track to go loose or slack on top.
The tracks were free to oscillate up and down at a central pivot. This feature improved the riding qualities of the tracks, and as each track would pivot independently very little movement was transferred to the body. This feature, along with a pivoting ski system, provided a snowmobile which rode smoother than any other snowmobile with which the author has had contact.

Two skis were provided which pivoted up and down fore and aft. (Figure 7.) Barrett also included a unique feature on the skis to provide banking in either direction and so improve the turning and sidehilling ability of the machine. (Figure 8.) The banking of the skis was controlled from the inside of the cab by means of a lever. These skis were constructed from wood reinforced with metal on the edges which extended down an extra inch into the snow.

Power was provided by a Ford V-8, sixty horsepower engine. The transmission was a four speed 1½ ton Ford truck transmission. The differential was from a Willy's 1948 model civilian Jeep. All of these units were very satisfactory, and little difficulty was experienced with any of the drive train mechanism. The overall weight of the vehicle was 2,600 pounds which gave a flotation characteristic of six-tenths pounds per square inch.

Under most snow conditions, this machine performed very well. Its speed was good, about thirty miles per hour top speed, and normally operating at fifteen to twenty miles per hour in favorable snow conditions. The machine was relatively quiet and on long trips, the most pleasant driving and riding of any vehicle produced at Utah State Agricultural College. This vehicle operated for three seasons on snow survey work in Utah and southern Wyoming. After this period of operation it was dismantled as the track arrangement and bogie wheel system had
Fig. 7. Barrett Snowmobile Number 3
Fig. 8. Barrett Snowmobile Number 3 as operated in blizzard conditions
Fig. 9. Mud conditions on a spring snow survey trip
Fig. 10. Wheel failure caused by mud conditions
worn until maintenance was a severe problem.

While the Barrett machine was being constructed, work was also being done on United States Geological Survey, Crosley powered vehicle. A bogie wheel system of seven bogie wheels, similar to the system on the Barrett No. 3 snowmobile, was installed on this small machine. This bogie wheel system worked very good but trouble was again experienced with the small Crosley engine and other drive components of the vehicle. After the 1948-49 season this snowmobile was discarded. One feature of interest of this small snowmobile as it was last modified was adapting to the small Crosley engine, a four-speed Chevrolet truck transmission which provided a very good range of gear ratios. This small vehicle operated well in most snows, but was always slow and was plagued with mechanical failure of one kind or another throughout its operational life.
Fig. 11. Frandee SnoShu Number 1 - inventors Roy France and Emmett Devine
CHAPTER IV
FRANDEE SNOWMOBILES

Frandeep SnoShu No. 1

During the winter of 1946-47, a snowmobile was constructed by two men at the college which has influenced all other snowmobiles which have since been built at the College. Roy France, head of the Automotive Department of the College, and Emmett Devine, who had charge of Vehicle Maintenance for the College, were the designers of this new vehicle. They procured parts on their own resources and constructed a vehicle which first ran early in 1947. As they were working with only their personal resources, the machine was constructed with whatever parts were available for the least amount of money. The engine used was a four-cylinder Model B engine. Although practically an antique, this engine provided excellent torque characteristics. The vehicle had a three-speed Ford transmission, and was equipped with front and rear differentials. These differentials were procured from early Willys 77 automobiles. The vehicle had three large wheels, which mounted 17 x 5.50 tires on each side. The thirty inch wide open centered track was driven from both the front and rear ends by friction. Driving this track from both the front and rear eliminated the problem of slippage as there was enough frictional area between the two wheels and the track to prevent slippage under all but extremely severe conditions, and then this slippage could be eliminated by further tightening of the tracks. This front and rear driving of the tracks has proved to be the most important single feature in snowmobile design developed at the College. This type of track drive has since been patented by France and Devine and has been used on several vehicles.
Steering of the vehicle was done by locking the brakes on either track and so transmitting power to each track separately through the spider gears of the differential. This steering arrangement made a very maneuverable vehicle. It does, however, produce rather severe stresses on the spider gears of the differential and some failure was experienced with the light Willy's differentials.

This vehicle, as first assembled, had no cab and so was very light, weighing approximately 1,600 pounds and having a flotation factor of one-half pound per square inch of track area which is a very desirable figure. The most important feature of this vehicle was its extreme simplicity. Most of the parts which gave trouble on previous snowmobiles had been eliminated, and the remaining moving parts were of rugged construction and simple design. All but the frame had been adapted from standard automotive units.

This first Frandee Snowmobile is still in operation and has experienced little or no failure due to faulty design. The few breakdowns which have been experienced have been caused by the designers having been forced to use second-hand automotive parts rather than from any overload placed on the parts from poor design.

**Frandee SnoShu No. 2**

Early in the spring of 1949, W. V. Iorns, project engineer with United States Geological Survey was present at a demonstration of the Frandee SnoShu No. 1. He was impressed by the operational characteristics of this vehicle and saw what he thought were potential features which would best meet the needs of the United States Geological Survey oversnow transportation problem. Arrangements were made with France and Devine to use their design in constructing a test model for the United States Geological Survey. Contact was made with the cooperative
research laboratory at the Collège which was under the direction of the Soil Conservation Service and the Utah Scientific Research Foundation. France was assigned the task of making preliminary drawings for a small vehicle to meet the needs of United States Geological Survey. The author, at that time shop foreman in the laboratory, was placed in charge of construction of the vehicle.

The following are some of the initial requirements listed by the United States Geological Survey which they thought were desirable in an over-snow vehicle. These features were to be used as a guide by France and the author in constructing this vehicle.

1. **Dry weight** not to exceed 2,000 pounds, and of such proportion that it can easily be loaded and carried on a light truck of not greater than one ton capacity.

2. **Have easily repairable motive power and power train** that is simple and absolutely dependable.

3. **Designed and constructed of such standard and obtainable material so as to be capable of reproduction of additional units at a nominal cost.**

4. **Provide comfort and safety for operating personnel and be simple in operation for inexperienced personnel.**

5. **Have cargo space and carrying capacity for two men and miscellaneous equipment needed in winter stream gauging (not to exceed 600 pounds.)**

6. **Capable of traversing the following types of terrain:**
   a. Snow covered with soft or sticky snow, with reasonable ease.
   b. Packed and settled snow, with a high degree of ease.
   c. Alternate snow and bare ground, with ease.
   d. Rough, rocky, and muddy ground, with ease.
   e. Shallow streams, with ease.
   f. Timbered areas, with ease.
   g. Side slopes, with safety.
   h. Steep slopes, with ease.

The author wishes to note the use of the above term "with ease". Use of this term by agencies to list the degree of performance of a
vehicle, is practically useless as it is a relative term. There are enough uncontrollable variables in the design and construction of a snowmobile without introducing these relative terms in the specifications for a new vehicle.

The following are specifications of the Frandee SnoShu No. 2 as completed and delivered to the United States Geological Survey. (Figures 12, 13.) These specifications are quoted from the field diary the author kept during the construction period of this vehicle.

1. Passenger capacity...two men seated; one fore and one aft of the engine. Bucket seats with air foam cushions.

2. Load capacity...600 pounds, including weight of men and gasoline.

3. Overall width...sixty-five inches.

4. Overall length...101 inches.

5. Overall height...seventy-two inches.

6. Engine and power train:
   a. Engine: Hercules ZXB3, four-cylinders, twenty-five horsepower at 3,700 revolutions per minute, bare weight, 170 pounds.
   c. Drive sprocket: Fifteen tooth.
   d. Driven sprocket: Forty-five tooth.
   e. Chain: Five-eighth inch roller type.

The engine is centered slightly forward of the center of the machine in reversed position with radiator toward the rear. The drive sprocket is welded on the transmission driven shaft and supported by a double bearing on the transmission housing. The driven sprocket is bolted to the back of the universal joint at the pinion shaft extension from the differential.

7. Axle and differential...Two Jeep differentials are used with the long axle housing shortened eight inches. This gives an arrangement whereby short axles are used throughout. The differentials are placed opposite each other, turned upside down to increase drive shaft clearance and directly connected with universal joints and propeller shaft to provide a four-wheel drive.
Fig. 12. Frandee SnoShu Number 2 - ski raised for travel over bare ground
Fig. 13. Frandee SnoShu Number 2 - a later modification permitted steering of ski from inside the cab.
8. Wheels...Eight wheels are provided with four on each side to give an even weight distribution along the full length of the tracks. The center four wheels are idlers operating on light spindles. All tires are 4.50 x 12 pneumatic and wheels are interchangeable.

9. Tracks...The tracks are specially built, each weighing 145 pounds. The belting used is Quaker Ironsides conveyor belting, three ply, with one thirty-second inch rubber covering on the inside and one-eighth inch rubber covering on the outside. Belting width is eight inches and total width of each track assembly is twenty-two inches. The cross cleats are made from one and one-eighth inch outside diameter, and one-sixteenth inch wall thickness chrome-molybdenum steel tubing deformed to heart shaped sections. Side hill gripping cleats are short tee sections of aluminum. The tire sturups are specially formed and welded from one-eighth inch by one inch mild steel.

This type track has demonstrated itself to be superior to any snowmobile track constructed to date. It has excellent flotation qualities, is smooth and quiet running, and will operate on any surface without danger of damage. Greater traction could be obtained by increasing the cleat size and spacing them farther apart. The cleats on the present machine are spaced on five inch centers.

10. Brakes and steering system...The four brakes are standard Jeep hydraulic with one inch hydraulic cylinder. Two one-inch hydraulic master cylinders are operated by hand levers for steering. Each master cylinder is connected by a split line to the brakes on its respective side of the machine, and steering is accomplished by slowing or stopping one track or the other.

11. Frame...The main support members of the frame are of two-inch airplane tubing rigidly attached to the front axle housing. Slightly smaller tubing, machined to slide inside the two-inch main tubes, are rigidly attached to the rear axle housing. These sliding joints are spanned with one-inch square thread jack screws for tightening or loosening the tracks. Lighter airplane tubing is welded in truss pattern to increase strength and to support the engine and cab. This provides a very rigid frame of light weight construction.

12. Starting system...Battery and starter with generator.

13. Gasoline...Eleven and one-half gallon cubical shaped tank, mounted near center of machine on side opposite battery.

14. Weight...Dry weight, 1,630 pounds.
15. Effective area of tracks...3,430 square inches.

16. Snow pressure...0.48 pounds per square inch (dry weight).

17. Snow pressure...0.60 pounds per square inch (loaded).

18. Transportation:...Can be easily and quickly loaded and carried on a one-ton pickup truck which has been provided with a flatbed.

A Willy's Jeep 4x4, one-ton truck was used for this purpose.

The machine, when completed, ran through a rather severe and elaborate testing period. The first deficiency in the machine discovered was that the engine was underpowered for this type vehicle. The small Hercules twenty-five horsepower engine should have had at least twice this horsepower to be satisfactory. The machine steered entirely by brakes as first constructed and under most snow conditions was able to maneuver satisfactorily. In deep powdered snow conditions, the fine powdered snow tended to sift into the brake drums and wet the brakes when pressure was applied to them. After pressure was released these brakes glazed with ice and the steering affect of the brakes became null. Late in the season, a single finned ski was adapted to this vehicle so the main means of steering was then done by the ski which ran in front of the vehicle and the brakes were used only to assist the ski in difficult locations. This steering arrangement, the author feels, is ideal. Vehicles which steer entirely by brakes, or some other means of metering power to the individual tracks, in extremely soft snow conditions, do not do a good job of steering. When one track is slowed down to make a turn, the opposite track digs in, and quite often, the vehicle turns in exactly the opposite direction desired. This condition was found many times, especially in the high Uintah mountain area of Utah.

The No. 2 model of the Frandee SnoShu was operated successfully
for several years by the United States Geological Survey and is still
in use in their stream gauging program in northern Utah and southern
Wyoming. It has, at the date of this writing, completed at least 3,000
miles of operation. It could be said that this vehicle was a mile-stone
in the development of snowmobiles at the Utah State Agricultural College.
First, considerable design work was done before construction was actually
started; second, only new materials and those best suited for the job
which were available were used; third, the quality of the workmanship
which went into this vehicle was kept very high. This later proved
to be a definite advantage, as no failure of any of the frame or other
main structural components has taken place since the original date of
construction. Another unique feature of this vehicle was the placement
of the engine in the center of this vehicle and locating the driver
right at the very front of the vehicle to give the machine a better
distribution of weight and also provide the driver with unlimited
forward vision while operating the machine.

**Frandee SnoShu No. 3 and No. 4**

In July of 1950, the author was authorized by Clyde to proceed
with the construction of another snowmobile for Soil Conservation
Service. This snowmobile was to be based on the design of France
and Devine's SnoShu.

The Barrett snowmobile No. 3 was dismantled and several parts
salvaged from this machine. The engine, transmission, and Willy's
differential still being usable, work was begun on July 20, 1950.
Progress was slow as most of the author's time was being used on the
construction of water and snow measuring devices for the coming snow
survey season, the snowmobile work being fitted into the slack periods.

There follows some general descriptive details of the Frandee
SnoShu No. 3 machine, from the field diary of the author dated December 1, 1950.

Engine: Ford V-8, 60 horsepower, Year 1940, engine is stock throughout.
Transmission: Ford 1½ ton truck, 1942 model.
Differential: Willy's civilian Jeep rear differentials. One differential is cut to switch the long and short axles to opposite sides to facilitate line up of the drive shafts. Ratio 43 to 8.
Transfer Case: Local manufacture, is of two sprockets and chain. Sprockets are one inch pitch, thirteen tooth and twenty-six tooth to give a 2 to 1 ratio. Chain is RC-80 light roller chain. Chain is tightened by an idler sprocket of sixteen tooth. This idler sprocket is placed so as to increase the contact of the chain on the drive sprocket.
Drive Shafts: Cut down Ford one ton pickup.
U-Joints: Ford Oly.
Tracks: one-fourth x twelve inch molded belting. Two x 2½ hickory grousers, one-eighth x 1 inch strap iron tracks guides and reinforcing strips.
Tracks are twenty-eight inches wide. Grousers are spaced on six inch centers.
Weight of machine empty: Approximately 2,250 pounds.
Area of single track: 2,016 square inches.
Weight/Area Ratio: .575 pounds per square inch.
Wheel tread: Forty-eight inches.
Wheelbase: Seventy inches.
Tire size: Five hundred x 16 inch four-ply Firestone.

The Frandee SnoShu No. 3 proved to have a definite advantage over the No. 2 Frandee built for the United States Geological Survey. It had more than twice as much horsepower, which was a definite advantage, and its overall large size tended to provide a little better flotation. The machine was not much heavier but had considerable more track area. The machine was short in length in proportion to its width. This helped when turning by use of the brakes. The short wheel base was a definite disadvantage in climbing, particularly as this vehicle had a high center of gravity, and when on steep hills the high center of gravity shifted too far to the rearward, causing the machine to dig in at the rear end of the tracks.

This machine had a new type grouser constructed from hickory.
Wood grousers had previously been used on Frandee SnoShu No. 1, but on that vehicle they were relatively thin flat grousers. On this Frandee No. 3, an attempt was made to design a grouser which would enter the snow gradually, and the tapered shape of the grouser tended to compress the snow and provide better traction. The grousers were relatively thick, providing a deep bite in the snow. This track gave excellent traction, but it did need higher tire guides as those used tended to dig the side wall of the tires causing side wall tearing and sometimes actually penetrating clear through, causing a blow-out of the tire. The 5.00 x 16 tires on this snowmobile were not rugged enough for use. The 5.00 x 16 tires were a relatively non-standard size, a fault which should be corrected on other machines, as a tire failure in remote areas causes serious replacement difficulty.

An interesting feature of the Frandee SnoShu is; should one tire be broken and blown out, one of the center idler tires can be put in its place as a driving tire and the machine operated for emergency periods without any idler wheel. This was done on several occasions, and in effect it provides at least two spare tires on this type vehicle.

The Frandee SnoShu No. 3 was operated during the 1950-51 season by Gregory Pearson, newly appointed snow survey leader for Utah. His main criticism of the machine was the frequent tire failure, due to improper tire guides, and the high center of gravity of the vehicle which limited its climbing, and on one occasion caused the vehicle to turn over. However, this turnover happened with a relatively inexperienced driver at the controls. In the opinion of the author, the successful operation of any snowmobile to a large extent, like an airplane, depends upon the ability of the pilot.

Following are some unedited entries from the field diary of the
Fig. 14. Frandec SnoShu Number 3
author. These entries are included so as to provide the reader with a viewpoint as to the type of tests made with these vehicles. It can be noted that usually many of the climatic and snow conditions existing at the time: snow temperature, air temperature, type of snow, etc., are included in these diary entries. All of these things materially affect the operation of any over-snow vehicle.

First test of Frandee SnoShu No. 3.
November 18, 1950. Time: 2:30 P.M. to 5:00 P.M.
Location: Sinks at Summit of Logan Canyon, Utah.
Weather: It had been warm and some rain turning into a very wet heavy snow with a lot of snow falling in a short time. Gusty wind in high ridges.
Temperature: About 25 degrees.
Snow depth was about 30 inches and most of it fell in the past 48 hours. Snow was extremely packing type, and soft, clear to the ground.
Operation: Most running was in second gear, needing first gear very seldom, and third gear being used only on slight downhill. Machine was sinking about 10 inches and much horsepower consumed in this heavy snow causing slow operation.
Steering mechanism operated well and is quite effective. Sno is packing on ski because no wax was applied before coming out today. The heavy packing snow is piling between cleats and tires, and is causing wheel slippage. Beveling grousers would correct this trouble. Tires are running with 30 pounds pressure. About 20 to 22 pounds would probably be better. Track tightening bolt-head broke and needs welding. More clearance above track is indicated as track is hitting platform. The snow piling on tracks, and lifting them off the tire aggravates this condition. Brakes may need shielding and exhaust pipes would help.

December 2, 1950. 1:30 P.M. to 4:30 P.M.
Location: Sinkd and south of Sinks about 2 miles at Logan Canyon summit.
Weather: Clear, cold, and windy.
Temperature: About 15 to 20 degrees.
Snow condition: Twenty-two inches of old snow with crust. Ten inches of new powder on top of old crust.
Frandee: No. 1, 2, 3.
Operation: Machine No. 3 was sinking 5 inches in the new powder. Further sinking was prevented by compression of new snow on old crust, although the old crust would not support a man on foot. A test weight of .575 pounds per square inch sank 5 inches. A weight of 1 pound per square inch sinks about 6 inches.
Operation: Most operation of Frandee No. 3 was in second and third gear. Top gear being used only in the old tracks.
or down hill. Machine No. 3 climbed hills of at least 35 percent, probably 45 percent. Machine No. 3 climbed slightly steeper hills than could No. 1,2 as No. 1 has shallow grousers and No. 2 lacks power. The No. 3 machine seems to be of very rugged mechanical construction. The grousers have been beveled on top since last test, and no packing troubles with tracks were experienced. The steering mechanism is very effective today as the fin readily bites into the crust. A very small turning radius could be maintained without use of the brakes. After brakes become wet, they lose about 50 percent of their effectiveness. Shields or different lining may be necessary.

Observations: An interesting observation was that on some steep slopes increased traction could be gained by spinning the tracks to get about 50 percent slippage. This method was effective a couple of times when an extremely slow crawl was not producing very good results, although the machine was not stalled. This spinning of the tracks is usually poor practice as in most conditions it will cause the machine to dig into a deep hole. No mechanical trouble was experienced by any of the machines in about 15 to 20 miles of operation. Frandee No. 3 was transported on a Dodge power-wagon which was pulling No. 2 on a trailer. Speed was very slow, taking about 1.5 hours to get to the canyon 32 miles. The lodge is dependable as it is a four-wheel drive, but it lacks power in the higher road gears. Economy of operations is also very poor.

In November of 1950, a demonstration of Frandee SnoShu No. 3 was observed by Arch Work, of Medford, Oregon, Soil Conservation Service Office, snow survey coordinator for the Western States. After observation of these tests, it was decided by Work that they would like to procure a vehicle for snow surveying use in Oregon in the Cascade Mountains. Authorization was given by Clyde of Soil Conservation Service, and actual construction on this vehicle was begun on the tenth of November 1950. The first test of this vehicle was run on the eleventh of December 1950, just one month from starting the construction. The relatively short construction time should be noted as this vehicle was constructed by the author working alone, in approximately twenty working days. This was made possible by the excellent simplicity of the Frandee SnoShu.

The Frandee SnoShu No. 4 was basically, in overall dimensions,
the same as Frandee SnoShu No. 3. (Figure 15.) However, a different engine and transmission was installed. The engine used was a seventy-three horsepower Willys Hurricane engine. This engine, while being dependable, is relatively heavy for the power produced. The transmission was a T-96 Warner three-speed transmission which gave good service and was very quiet during operation.

The following are entries from the field diary of the author, and describe the first tests of the Frandee SnoShu No. 4 and other comparative vehicles.

Date: December 9, 1950. Time: 2:00 P. M. to 5:30 P. M.
Location: Tony Grove Canyon and Lake.
Weather: Clear.
Temperature: About 30 degrees.
Snow condition: Heavy, grainy snow at low altitudes. Above about 7,000 feet, there was 1 foot to 18 inches of fluffy powder snow, with no crust underneath. Snow depth, 3 feet, impossible for man to walk without sinking to thigh depth.
Operation: Left Tony Grove Ranger Station with three machines: Frandee No. 1, 3, 4. First operation of No. 4 was today. Climbed up canyon to flats just below the lake where we tested climbing ability, sidehilling, and steering characteristics. All three machines sank an average of 5 to 7 inches and Frandee No. 1 riding a little the shallowest. No. 4 machine has more power and speed than any of the earlier machines, but it is handicapped in some difficult spots because it does not have a four-speed transmission. The steering mechanism on all three machines works excellent.
Changes to be made in No. 4 machine follow: (1) Tighten steering gear; (2) improve throttle action; (3) change starter location; (4) install air cleaner; (5) install tailpipe clamp; (6) add top brace to steering wheel shaft; (7) brace radiator diagonally; (8) check brake adjustment; (9) check transfer case for noisy operation; (10) grease drive shaft.

Drop test: (A) .575 pounds per square inch to depth of 33.4 inches. (B) One pound per square inch sank 5' 3/4 inches. (C) Frandee sank about 7 inches.
These tests were made in heavy grainy snow.

December 14, 1950. 11:00 A. M. to 5:00 P. M.
Location: Tony Grove Lake.
Weather: Cloudy with a medium snowfall in the afternoon.
Temperature: Just below freezing.
Snow Condition: At low altitudes, a firm crust. At elevation of the Lake, there was a very slight crust with a very fine sugary snow underneath. This snow would not pack at all because temperature was below freezing.


Operation: Left Tony Grove Ranger Station about noon and ran on packed snow up to the lake. Frandee No. 3 and No. 4 were the machines being run. Only a crust condition. It was possible to climb and sidehill on very steep slopes. Climbed an estimated 60 percent slope which was steep enough to hazard losing control of machine in descending the slopes. In the soft snow, it was possible to climb and sidehill about 35 percent slopes. Both machines are continuing to show superior maneuverability and steering qualities. No mechanical trouble except a bad spark plug in No. 4 cylinder, left bank of Frandee No. 3. Changing the ski attachment on No. 3 to the type used on No. 4 machine would speed assembly and dis-assembly of the steering unit to machine frame. Chain case on No. 4 is still a little noisy. The aluminum cab on No. 4 is extremely noisy and very objectionable. It must be removed if the operator is going to be able to hear the engine, etc.

Saturday, December 16, 1950.

Locations: Tony Grove Lake
Weather: Clear weather, no precipitation.
Temperature: Slightly below freezing.
Snow condition: At low altitudes, a heavy crust. At about 7,000 feet, a soft snow that is powder which is turning slightly grainy. The soft snow shows little compaction after machine passes over it.

Operation: We left Tony Grove Ranger Station at about 11 o'clock for the purpose of testing and demonstration No. 3 and No. 4 machines to fellows from the Medford, Oregon office. Drove to Tony Grove Lake. Both machines climbed a measured 25 degree slope and sidehill a 30 degree slope. This performance was on a crusted snow surface. The No. 4 machine, with the Willys Hurricane engine has quite a lot more power which is a definite advantage in soft deep snow. The machines both performed very well, and Work and Nelson seemed well pleased. No mechanical trouble of any kind. Broke one track cleat with the No. 3 machine when it hit a large rock at about 20 miles per hour.

Friday, December 22, 1950.

Location: Sinks at Logan Canyon Summit
Weather: Clear at high elevations. Very foggy at low altitude.
Snow Condition: A very sugary snow and the fog had been con-
denning each night and piling up heavy frost, and it forms a very difficult snow for operation of snow vehicles. This snow will not compact and a fellow sinks up to his knees in the tracks after a snow machine has passed. This snow requires a terrific amount of power to make any headway. Often necessitating operation in first gear.

Operation: We left the summit and went south through the Sinks. Then we turned up a long ridge in a westerly direction until we reached the top. Turned south again down a canyon and then circled around to the Sinks. Going down the canyon it was necessary to negotiate a sidehill of 55 to 60 percent. This sidehill was steeper than any I have negotiated before in any machine. The machine had to keep its front uphill at an angle and quarter around the slope. To have attempted to go straight around the hill, I am sure, would have tipped the machine over.

Saturday, December 23, 1950.
Location: Cowley Canyon to White's Bed Grounds.
Temperature: Below freezing (about 25 degrees).
Snow Condition: Sugary, grainy snow with about 6 inches of hoary frost. This snow will not compact. Machine only sinks about 4 or 5 inches, but requires first gear to operate in most conditions.
Operation: Drove truck (power wagon) about 3 miles up Cowley Canyon where about 6 inches of crusted snow stalled it without chains. Drove No. 3 snowmobile up Cowley Canyon to Summit and then up Skyline trail road to White's Bed Grounds. Operation was mostly in second gear as the snow would not compact and rolled and tumbled under tracks. If the weather would change and put down a little new snow, it would improve conditions for travel. Windbreak front is on the machine but the machine needs the top as the exhaust gases swirl up and cause discomfort to passengers. No mechanical trouble of any kind.

Wednesday, December 27, 1950.
Location: Tony Grove Lake and Sinks at Canyon Summit.
Weather: Clear, sun, and slightly below freezing weather.
Snow Condition: Sugary, grainy snow. Very hard going as the snow is small grains of ice and will not compact.
Operation: Made a run to Tony Grove Lake. The Machine No. 3 performs very well when not loaded too heavily. With one man in it, it climbed the big hill east of the lake. Sidehill and maneuverability are excellent. Came back to highway and loaded No. 3 on truck, and then followed Devine with No. 1 machine to the Sinks area. Operation at the Sinks was on grainy snow, and required lots of power, but performance was still very good with no more than two men aboard.

Friday, December 29, 1950.
Party: Senator Wallace F. Bennett, Dr. E. G. Peterson, President Lewis L. Madsen, General Timberlake and his party,
George D. Clyde, Lincoln Gallacher, Dean J. E. Christensen, Emmett Devine, Jim Hardman, Ross W. Eskelson.

Location: Sinks Area, Logan Canyon.

Weather: Cloudy and threatening snow, slightly below freezing.

Snow Condition: Ten inches of new powder over about three feet of grainy snow. Man sinks about to thighs in trying to walk in snow.

Operation: This trip was for the purpose of demonstrating the snowmobile to Senator Bennett and Army representatives. The machine No. 1, 2, 3, all performed very well, but No. 2 is still definitely under-powered. Later in the day, after snow settled slightly, performance improved and nearly all terrain could be traversed very easily. No signs of any mechanical trouble. Machine operated with a cab on it for the first time. Cab is a little too large as it will permit carrying too much excess junk on trips.

The Frandee SnoShu No. 1 was transferred to Medford, Oregon, in late December of 1950.

The author, through Clyde, Chief of the Division of Irrigation, Soil Conservation Service, requested that a full report of the operation of this vehicle be returned to Logan to assist in the design of further vehicles. Under Clyde's direction, R. A. Work, supervisor of snow surveys for Soil Conservation Service with headquarters at Medford, Oregon, was assigned the responsibility for making a comparative analysis of the Frandee SnoShu No. 1 and Tucker SnoCat Model 423.

The comparative test runs were made during the winter of 1950-51 and the results of these tests were reported to the author in April 1951. The report, as returned to the author, is included in the Appendix I of this study in an unedited form, as he feels that in this way it most accurately explains the typical problems encountered by operators of over-snow vehicles. The report includes narratives, statements, from several different operators, which eliminates the chance for the report to be biased in favor of one vehicle or the other. At the author's request, the comments by the various operators were written during or immediately following completion of any of the tests which tends to eliminate the chances of the operator describing what he wishes
The author, after carefully observing the No. 3 and No. 4 snowmobiles in operation, reached some definite conclusions as to what he felt was a proper design for an over-snow vehicle. The main criticism of the No. 3 and No. 4 machines was that they had too short wheel bases, and high centers of gravity which contributed to their general unstability, particularly in climbing steep hills and sidehilling. The conclusion reached by the author was that an improvement could be made in the Frandee SnoShu if a longer wheel base were used and four wheels used on each side instead of three. Widening out of the vehicle would allow the engine to be lowered between the tracks rather than mounting it above them. This lowering the engine would, of course, lower the center of gravity and with the longer wheel base would provide much better stability during operation.

These views were expressed to several of the author's colleagues. However, little enthusiasm could be generated for this type vehicle as it was generally felt that the vehicle would be large and unmanageable in snow. Devine, one of the original Frandee SnoShu designers, concluded that there may be some merit in the system, so he and the author decided to construct a vehicle and test this feature. This machine was constructed and financed by Devine and the author, consequently expenses were kept to a bare minimum by use of whatever materials were available for the least cost.

About March of 1950 two automobiles were purchased, one a 1936 Plymouth sedan, and the other a 1935 Plymouth sedan. This choice of vehicles was dictated by the relatively cheap price. It did turn out, however, that the two vehicles had the differentials of the same type which provided the basic components for the next snowmobile. With the
Fig. 16. Frandee SnoShu Number 5
help of France, the aforementioned men disassembled the automobiles, saving all parts that they felt they might use in the construction of the vehicle. Scrap water pipe in short lengths was welded together to form the framework of this No. 5 machine. Again the choice of materials being dictated by the costs, exactly nothing in this case as it was procured from scrap.

While the author proceeded with the assembly and construction of the chassis, Devine attempted to make one useable engine from the two engines removed the automobiles. By the first of May, 1950, the chassis was complete and the engine had been installed. The general layout of the vehicle, and especially the apparent low center of gravity made the builders feel rather enthusiastic about the potential of this vehicle. However, at this time, all of the snow available for testing had melted and so enthusiasm lagged until the following autumn. Little work was done on the vehicle during the summer of 1950. The author did, during his spare time, proceed with the construction of a transfer case for the vehicle.

With the coming of the first snows in November of 1950, interest in finishing the No. 5 Frandee SnoShu again rose and all spare time of Devine and the author was then devoted to the finishing of this machine. The vehicle was completed and ready for its first test run by January 27, 1951. The following are entries from the field diary of the author for this date, and describe the first test runs of this vehicle. Additional entries are included; one describing a trip into the Mirror Lake region of the High Uintah Mountains in February, another to the Washington Lakes snow courses, and the last, a trip to the summit of Logan Peak, east of Logan, Utah.

The entries from the field diary of the author are included unedited
to enable the readers to obtain a picture of the conditions and observations that take place during an actual run of the snowmobiles. The reader should recognize that most of these field notes are relatively short and sometimes sketchy and incomplete because of the difficult conditions under which they were compiled. Only one who has worked consistently in mountaineous terrains and in temperatures which often run to 45 degrees below zero, can appreciate the difficulty of running satisfactory tests and keeping accurate records under these conditions.

The taking of photographs of the vehicles, a relatively simple operation under normal conditions, became an operation of extreme complexity when temperatures hovered around 30 degrees below zero. The photographer was faced with the problems of frozen or slow shutter speeds, brittle or cracked film. Exposure meter readings were distorted because of the overall whiteness which surrounds the subject, and many other difficulties. The author tried several different makes of camera before finding one which consistently would maintain even reasonably accurate shutter speeds under cold conditions. It was not even practical to attempt to keep the camera warm before taking the pictures as this resulted in moisture and fogging difficulties with the lens when the camera was changed from warm to cold, and back to warm temperatures.

Saturday, January 27, 1951
Completed Frandee No. 5 and ran it around college campus. It appears to have excellent power, but can’t tell much as snow is not deep enough around the campus.

Sunday, January 28, 1951
First trip with Frandee No. 5. Weather, cold, snowing. Devine and Eskelson went from Old Juniper Lodge up past the head of Cowley Canyon. Ran in second gear going up and in direct drive coming down. Steering ski needs a little deeper fin for soft snows. Climbing performance in cold, sugary snow was excellent. Several very steep hills were negotiated. We went half way up to White Bedgrounds, and then started for home as the snowstorm and wind were extremely unpleasant.
January 30, 1951.

Davine and I took Professor Daniels of Forestry Department, Utah State Agricultural College, into the area south of Sinks, to get weather instruments left there last fall.

Weather, cold and clear (0 to 10 degrees.)

Measured snow temperature, about 3 degrees colder 6 inches under surface of snow than on surface. Snow condition, soft and sugary; man sinks to knees.

Frandee No. 5 ran well all day operated in second gear and high gear 90 percent of the time. Professor Daniels commented that we made the trip as fast as they usually do in a truck in the summer.

February 21, 1951.

Party: Eskelson, Davine, Gallacher, Clegg.

Weather: Clear and just below freezing temperature most of the day.

Snow condition: Fine powder snow about 1 foot to 16 inches freshly fallen last night. Snow compacts in track of machine in about one hour, after machine has passed over snow.

Drove to Trial Lake from Duschene Tunnel entrance.

Left Trial Lake and went over Baldy Pass to Mirror Lake and Camp Steiner. Measured new snow course at head of Hayden Fork of Bear River. Card Clegg says it is the first time any mechanical transportation has been over Baldy Pass to Mirror Lake Basin in the winter. Clegg says he has been to Mirror Lake in May, but this is the first time to his knowledge anyone has been in there this early, and he should know as this is forty-two years he has been coming into Trial Lake each winter.

Defects and recommended improvements: (1) Too little power (need 100 horsepower). (2) Too high geared, need 3 to 1 ratio in transfer case. (3) Need larger, deeper fins on ski, and for machines this large, the ski could be further out in front of machine. (4) Need more reliable motor and four-speed transmission. This No. 5 (Plymouth) has too much junk in it to ever be dependable.

February 25, 1951.

Returned from Trial Lake to Tunnel Entrance in morning and on to Logan in afternoon. Davine stayed in Coalville to make Chalk Creek run tomorrow.

About March 15, 1951.

Trip into South Sinks with ski class.

Weather: Cold and clear, about 15 degrees F.

Snow: Cold granular snow.

Took No. 3 and No. 5 machines. No. 3 now has 100 horsepower engine but it will not begin to follow No. 5.

No. 5 has pulled as many as thirty skiers.

At 4:30 P. M. left to rescue girl with broken leg. Davine and I brought her out on a ski toboggan. Got out
March 30, 1951.

Devine, Clegg and myself left Kamas at 5:30 A.M. Went over Mirror Lake summit and measured stream crossing of Hayden Fork, Bear Head courses. Came back and measured Lost Lake and Trial Lake. Took the machine up Washington Lake Hill and over onto Washington Long Lake Snow Course. First time a machine has done this in deep powdery snow. Back to Trial Lake and out to Kamas in evening. Machine performed very well.

Measured Soapstone and Beaver Creek courses the next morning, and then returned to Logan.

Machine needs more power but the traction and overall operation is excellent.

April 5, 1951.

Trip to Summit of Millville Canyon.
Weather: Warm, partly cloudy.
Snow: Wet and very rotten in most places.
Climbed to summit of Millville Canyon and on north to peak, elevation of 8,963. Machine performed excellent but could use more power. Traction was very good in all cases. Traveled over long stretches of sagebrush and rocks with no difficulty. The steering fin is quite effective when on drifted snow.

April 7, 1951.

Trip to Summit of Logan Peak by way of Providence Canyon, with No. 5 Frande SnoShu.

Because of the limited entries on the trip to Mt. Logan, further explanation is made here as this trip was an exceptional test of the vehicle’s performance.

It was necessary to leave Logan very early in the morning so as to have a frozen crusted condition for the vehicle to travel on in the area above the rock quarry in Providence Canyon. The area immediately above the quarry is extremely steep and the machine must follow a very narrow gulch, surmounting numerous large rocks and fallen trees.

From the peak of Providence Canyon, it is a matter of picking a path along the various ridges to reach the relatively flat plateau area south and east of Logan Peak. From this point, a ridge, which approaches the peak from the south and then finally comes into the peak directly from the east, is followed with the snowmobile.

The vehicle was able to reach a point approximately 200 yards from the actual summit of Logan Peak. At this point, Devine and the author decided it was inadvisable to go further with the snowmobile, as the ridge we were following became a peaked type drift approximately four feet wide, with a direct drop of several hundred feet on either side. While the machine could probably have straddled this drift and reached the actual peak, the
chances of starting a snowslide and loosing the machine and perhaps injuring ourselves, influenced our decision to leave the machine and complete the final 200 yards on foot.

The peak afforded us a beautiful vantage point from which to view the entire Cache Valley. After taking several pictures and leaving evidence on the peak to verify our having reached the peak, we returned to the machine and proceeded to back-trace our path to Logan.

Upon returning to Logan and relating our having reached the top of Logan Peak with the vehicle, we were greeted with no small amount of skepticism by many of our colleagues, so accordingly, the following morning, April 8, 1951, we arose before daylight and duplicated this feat with the No. 5 and No. 3 Frandec SnoShus. This time we included in our party, Hardman of Utah Scientific Research Foundation, and Lincoln Gallacher, Administrative Assistant with the Soil Conservation Service offices in the College.

Devine and the author ran the vehicle until the time of the melting of the snows in the spring of 1951. This testing period was invaluable in trying to determine just what made a good snowmobile. It is the opinion of the author that one of the faults of the previous snowmobile program at Utah State Agricultural College has been the minimizing of the testing period. The machines have been completed and then pressed into regular service, such as snow survey work, with little or no deliberate testing done by the people who have built the machines. The author feels that this is still a fault in the present over-snow vehicle programs at the Utah State Agricultural College.

It is difficult to over estimate the value of this testing period and practically all major improvements in snowmobiles at this College have been the result of the few times some deliberate tests have been run. While testing periods may, at the moment, seem expensive in both time and materials expended, the author feels sure that over a longer period of time, these tests pay off many times over in preventing duplication of mistakes, and in helping to correct defects as soon as possible rather than allowing these defects to remain in machines that
are delivered to the final user.

In mid-May of 1951, an inquiry was received from the American Telephone and Telegraph Company relative to the Frandee SnoShu. They were interested in procuring some over-snow vehicles for use in maintaining the micro-wave relay stations they were installing across the country at that time. Representatives from their New York office came to Logan and made a preliminary inspection of the Frandee SnoShu No. 5. At this time it was decided to send the Frandee SnoShu No. 5 to the Reno, Nevada area where the administrators of the Pacific Coast Division of the Bell Telephone Company could view the performance of the vehicle in the local elements.

Devine was sent to Reno where he proceeded to give a demonstration of the Frandee SnoShu in the Mt. Rose area. He later took the machine out on the Mud Flat area, just east of Reno, and demonstrated for the officials the machine's ability to traverse extremely soft and muddy areas. During one phase of the demonstration, he proceeded to enter and leave a terrific bog with large holes in it where some previous machine tested had been stuck and had been removed with means of a winching cable. The officials of American Telephone and Telegraph Company were favorably impressed and subsequently sent Mr. Upgreen, of the Denver office of Mountain States Telephone and Telegraph Company, and Mr. J. S. Gray, of the San Francisco office of the Pacific Bell Telephone Company, to Logan to make preliminary arrangements for the construction of several vehicles for their use.

It should be noted here that the vehicle used in these demonstrations was the one which most people concerned with the snowmobile program had decided was too large and unmanageable, and also that the vehicle was constructed only from junk parts, yet it made a creditable
showing during this testing period. After Devine returned to Logan, he and the author began making preliminary plans for constructing a test vehicle for American Telephone and Telegraph Company.

**Frandee SnoShu Model B**

By June of 1951, the author had left his position as Laboratory Research Mechanic with the Soil Conservation Service, and had entered the employ of the Utah Scientific Research Foundation, an affiliate of the Utah State Agricultural College. The Utah Scientific Research Foundation had, at this time, decided to enter into an agreement with France and Devine, the inventors of the Frandee SnoShu, with the intent of assisting the inventors to obtain patents and to develop the Frandee SnoShu to a point where it was commercially successful. A licensing agreement was arranged with the inventors and early design work started on the next models of the Frandee SnoShu.

In May 1951, approximately the same time American Telephone and Telegraph Company had shown interest in the Frandee SnoShu, an inquiry had been received from the Civil Aeronautics Administration, Alaska Division. A representative from Unalakleet, Alaska had arrived in Logan and observed tests of the Frandee SnoShu and arrangements were made for procuring one test vehicle for use by the Civil Aeronautics Administration in the Alaska area. The vehicle for the Civil Aeronautics Administration was designated as Model B Frandee SnoShu, and work was immediately begun on its construction in June of 1951. A few weeks later, work was also begun on two vehicles for the Pacific Bell Telephone Company, and two vehicles for Mountain States Bell Telephone Company.

The Model B Frandee SnoShu was copied basically after the old No. 5 machine built from the scrap Plymouth parts. It had four 6.00 x 16 wheels on each side and they were spaced slightly farther apart than
the wheels on the No. 5 Frandee SnoShu. The wheel base was eighty-eight inches and the tread fifty-seven inches, the same as the standard tread of a Ford F-1 pickup truck.

The first Model B. machine, which was Serial No. 6, was delivered to the Unalakleet, Alaska, Division of the Civil Aeronautics Administration, was equipped with a Continental F-226 engine of 100 horsepower. A Warner four-speed transmission and a transfer case which reduced by a ratio of 16 to 42. Five other Model B. machines were constructed and were all equipped with six-cylinder Ford engines of 25½ cubic inches displacement and 112 horsepower. Two of these vehicles went to the Pacific Bell Telephone Company, two to Mountain States Bell Telephone Company, and one to Medford, Oregon, Office of Soil Conservation Service. These Model B. machines were constructed and delivered between July of 1951 and January of 1952.

Many minor changes were found which were made soon after the vehicles were put into service. A few of these changes were: brake shields had to be added to prevent the brakes from becoming wet, the track cleats had to be thinned immediately under the tire to prevent icing conditions. Some gear failure in the F-1 Ford differentials used also showed up. However, it was not practical to replace these differentials with a different type model. The type of differential was changed on a later machine.

Frandee SnoShu Model A

The Frandee SnoShu Model A. was a small machine which was custom built for the United States Geological Survey office in Sacramento, California.

The Utah Scientific Research Foundation was rather reluctant to proceed with the construction of this vehicle because of the previous
experience they had had with the small three wheel type Frandee SnoShu which were not well balanced and underpowered. However, the United States Geological Survey, being desirous of operating smaller machines, decided to have the Utah Scientific Research Foundation go ahead and construct the machine to their specifications. Only one of these machines was constructed and the success of it was only fair.

The Model A Frandee SnoShu was equipped with an F-162 Continental Engine of approximately sixty-five horsepower. A Borg Warner four-speed transmission was used and Willy's civilian Jeep differentials. A transfer case of 15 to 42 was used. The Willys Jeep differentials were not entirely satisfactory as they had rather poor brakes, the brakes being of insufficient capacity to exert enough pressure to effect efficient turning of the vehicle.

After construction of the Model A was complete, and test runs made, the Utah Scientific Research Foundation concluded this vehicle was what might be termed an "awkward size". It appeared that to be successful, a machine must be as large as the Model B, because the components have to be practically as heavy in the smaller Model A., and yet the Model A. had considerable less track area. The other alternative was to go to an extremely small light machine would could then be equipped with lighter components and a satisfactory weight-area ratio achieved.

Model C Frandee SnoShu

In May 1952, the results of the past winter's testing of the vehicles was consolidated and early construction of another machine was begun. This vehicle was for the Pacific Bell Telephone Company for use at Donner Summit and Emigration Cap. This particular area has some of the heaviest snowfall of the United States, and is located at the point where the Southern Pacific train was snowed in for several
Fig. 13. Frandee SnoShu Model C
days during the winter of 1952.

In most components, this Model C was the same as the Model B. The wheel base of the Model C machine was extended to ninety-six inches, an increase of eight inches, with the rest of the machine and the cab remaining the same size as the Model B. This increase in wheel base length added considerable area to the track with very little increase in the weight, making a more favorable weight-area ratio and reducing the amount of apparent shift of the center of gravity, of the vehicle, to the rearward while climbing on steep slopes. This vehicle performed very well. The differentials proved to be too light to withstand constant use of the brakes in turning. The spider gears failed under the first test-run, however, these gears were replaced by the factory and a comment by the factory people was that the gears appeared to have been improperly heat-treated.

**Frandaet SnoShu Model D**

The Model D Frandaet SnoShu was similar to the Model C, with the exception of the differentials. The differentials were increased in size from the type used in the F-1 Ford pickup truck to the type used in the F-2 Ford pickup truck. The F-2 differential had larger brakes and were considerably heavier in the spider gear assembly. The spider gear assembly is the unit which usually fails while steering through a differential. This is, admittedly, not the best way of steering a vehicle of this type. A better method would be to use a means which would meter the power in any amount desired to either track, such as a planetary arrangement, a torque converter, or some other type of metering device. Torque converters as are used on some late model crawler type tractors, would be ideal for this purpose, however, those which are manufactured are much too heavy for use in over-snow equipment.
Approximately twenty machines of the Model D type were built and located in the United States, Canada, Alaska, and Greenland. Several of these vehicles were procured for test by the Transportation Corp of the United States Army, and were run through a series of tests at Fort Churchill, Canada, Big Delta, Alaska, Thule Airforce Base in Greenland, and Aberdeen Proving Grounds in Maryland. The reports from these tests indicated that the vehicle was capable of handling all soft snow conditions and would extricate itself from any difficulty in soft mud, marsh, and muskeg. The real Arctic transportation problem is, however, not one of extremely deep soft snow, but rather one of a variety of surfaces such as intermittent ice, pack-ice, wind-driven snow, pressure ridged ice, muskeg, open water, etc. Any machine, to be truly successful under all these Arctic conditions, will have to be a very versatile machine including having the ability to be an amphibious vehicle.

These tests indicated that the Frandee SnoShu could be used in mountainous areas where there was deep soft snow, but it would have only limited possibilities as an Army vehicle as the design of this vehicle was too specialized for any practical army use except for scouting and limited supply purpose.

Frandee SnoShu Model E

In the summer of 1953, the final change was made in the type of design that the Utah Scientific Research Foundation had been pursuing in over-snow vehicles. The model F-2 differential produced by and used in the Frandee SnoShu was discontinued and so a change in this unit was necessary. The differentials chosen were from a 250 General Motors Company truck. These differentials were heavier, and much stronger in the spider gears. The brakes were of greater area. This increased brake area proved to be extremely valuable. Several vehicles have been
produced using these larger differentials and brakes, and have proven themselves to be satisfactory for the type of steering used on the Frandee SnoShu. No brake or gear failure has shown itself up to this time and the steering effort by the operator was reduced considerably.

In later models of the Model E machine the type of engine was also changed. The use of the 254 cubic inch side valve Ford engine, being discontinued and replaced with the new design overhead valve six-cylinder Ford engine. This engine is very desirable as it has a high power-weight ratio, and an excellent full pressure oil system which maintains good lubricating facilities through all the parts of the engine under any angle the vehicle might be operated in.

The Frandee SnoShu, as finalized in the Model E, is capable of doing an excellent job in the soft type of snow found in the mountainous areas of the west. However, the vehicle is limited in its versatility and because of its relatively high cost, this model will find only limited acceptance. Only those users who absolutely must operate in the mountains in the winters can afford these vehicles. One of the serious drawbacks to all snow equipment that has been produced and observed by the author has been the relatively high price which puts it out of reach of many who might wish to use it and making it expensive for even large corporations to own and operate.

The Frandee SnoShu Model E machine will probably not be pursued any further by the Utah Scientific Research Foundation because it is now directing its efforts toward a more versatile Arctic type vehicle. The Utah Scientific Research Foundation is also attempting to produce a light weight, versatile small snowmobile intended for use by small organizations and private users whereas the larger vehicle would serve the purpose of the government and other agencies which must carry larger
amounts of supplies, equipment, and men into the snowbound locations.
During the summer of 1952, the author, being interested in seeing what could further be done in the construction of a small snowmobile, proceeded to procure materials for this purpose. This machine was built as an avocation and the materials used were what could be procured rather than what was desired. Use of the Utah Scientific Research Foundation shops were graciously offered by the officers of the Utah Scientific Research Foundation. The author procured a Crosley engine, a four-speed Chevrolet transmission, and some other scrap parts from one of the previous vehicles of United States Geological Survey through assistance of Von Iorns, project engineer for United States Geological Survey. With this equipment a start was made on producing a very small vehicle.

A light framework of aircraft tubing was welded up and a vehicle finished that weighed approximately 1,150 pounds. This gave an excellent flotation of about seven-tenths of a pound per square inch of area. (Figure 20.) The only means of steering this light vehicle was by use of a single finned ski in front, which worked very well in most snow conditions. This type of steering, of course, prevented it from any but limited use on bare ground. The vehicle showed good climbing and very good sidehillling characteristics, being perhaps the best sidehillling of any vehicle produced, so far. It had many mechanical troubles, especially with the Crosley engine. The engine used, had seen long hard service, and although it was rebuilt it never proved reliable. Further use of these engines has proved their unsuitability for over-
snow vehicles. An engine with a little more margin of reliability would have to be used for over-snow vehicles.

This small snowmobile was later used by Soil Conservation Service in making some of their local snow surveys, and since has been in use in the southern part of the state for the snow survey program in that area. Tests of this first small vehicle were run, and observed by several snow survey people who indicated that it was more nearly the size vehicle desired for snow survey work. The snow survey men are interested in two main characteristics of the vehicle; one, a light weight portable machine so it can be carried with relatively light trucks, and second, that the cost must be in the neighborhood of $3,000 to prevent a large capital investment for the snow survey program.

The Soil Conservation people, after seeing the small vehicle run, decided to obtain two pilot models. These models were constructed, one using a Crosley engine, and the other using a small Waukesha engine. The Crosley engine again proved unreliable, although a new engine was used, and the Waukesha, while fairly reliable, was too heavy for use in the small vehicle, and the weight instead of being 1,100 pounds, as in the first machine put together by the author, was near 1,500 pounds which made the vehicles too heavy to achieve the performance desired. In addition, the Soil Conservation people insisted on adding a cab so the operators could ride in relative comfort, which again handicapped the vehicle with added weight. On a light vehicle of this type intended for snow survey use where men must live in the mountains for several days, the author feels that a cab is definitely a luxury which cannot be afforded as it greatly limits the operational characteristics of the vehicle. The main requirement of any vehicle is that it must arrive at the destination intended, and adding unnecessary
Fig. 21. Eckelson Motor Sled Model 42-1
equipment, however slight, definitely reduces the capabilities of any small snowmobile. The smaller the snow machine, the more serious these added luxury features become.

Having had limited success with the small motor sleds during the winter of 1952-53, Soil Conservation Service authorized the construction of three more vehicles in the spring of 1953. These three vehicles were to use air-cooled engines. The only air-cooled engines available, of sufficient horsepower which could be adapted to these snowmobiles, were the motorcycle type engine manufactured by Harley Davidson Company. These were engines of seventy-four cubic inch displacement and approximately fifty-five horsepower. These engines gave an excellent horsepower weight-ratio, however, they had other serious limitations. The main limitation being a severe vibration characteristic which is inherent in all engines which are two-cylinder, forty-two degree angle V-type engine. This vibration characteristic is not serious when the engine is used in a motorcycle, as the engine is mounted with the plane of the rotating fly wheels parallel to the long axis of the motorcycle. In motorcycles the engine is operated most of the time in its high revolutions per minute range, where the vibration is negligible because of the closeness of the firing impulses of the engine.

The first vehicle using the Harley Davidson engine mounted the engine with the fly-wheel plane parallel to the long axis machine and the power was transmitted to the rear axle through a four-speed transmission and by chain drive. The use of the chain drive was not desirable as several chains and sprockets with counter shafts were necessary to reduce the revolutions per minute of the engine to those necessary at the rear axle. Each set of chains induced problems of proper lubrication and tightening which became too complex for satisfactory
Fig. 22. Eskelson Motor Sled Model 4Z-2
operation in the severe field conditions under which a snowmobile must operate.

The last two vehicles which used Harley Davidson engines, placed the engine fly-wheel plane at right angles to the long axis of the snowmobile. An attempt was made to then drive from the engine by a double universal joint through an automotive type clutch and transmission. The author here made a serious design mistake as the inherent vibration characteristics of this engine would not allow power to be transmitted through this universal joint arrangement, and after a few hours of operation these joints failed. However, the author wishes to point out that these machines were delivered without making adequate tests before delivery, which further backs up the point earlier made in this study, that there is no substitute for full and adequate testing of any vehicle before an attempt is made to offer it to any user. Although these vehicles were delivered during the summer months of 1953, preliminary tests could at least have been run without the tracks on a wheel type dynamometer which would have exposed the serious design limitations of this vehicle.

The engines in these vehicles have since been changed and the vehicles have been used in the Oregon area of the snow survey system. The addition of the Willys engine has increased the weight until the operational characteristics and the desirable features of the vehicle have been ruined. Much was learned from these small vehicles, in the way of what not to do. The author, of course, accepts full responsibility of the design errors that were made in these vehicles.

There is definite need for a small snowmobile weighing approximately 1,000 pounds and which can negotiate slopes of forty-five percent either climbing or sidehilling. The price to be acceptable by the
general public would have to stay under the $3,000 mark. Such a vehicle would find wide acceptance with farmers, trappers, telephone repairmen, power and light crews, and many people who find need to go into the mountains during the winter months. Not the least of the possibilities of a small vehicle of this type is the sporting aspect for skiing excursions and scenic trips. The author and many others who have operated snowmobiles have found many hours of enjoyment after having been hauled to the top of some distant mountain where they could obtain many miles of skiing while returning from the spot the vehicle had left them.

Sun Valley and other resorts have purchased and tried several types of vehicles, but they still feel that the type of vehicle to meet their needs has not, at this time, been constructed.
In September of 1953, the author left the Utah Scientific Research Foundation to accept his present position in the Welding Department at the Utah State Agricultural College. At that time it looked as if the demand for over-snow vehicles had perhaps been over-estimated as the inquiries for snowmobiles were starting to lag. Soon, however, interest began to pick up with inquiries being received from several organizations. At that time, James A. Hardman, Project Director of the Utah Scientific Research Foundation, took over the snowmobile project and since that time it has been under his direct design jurisdiction. Hardman's first efforts were directed toward investigation of a small vehicle similar to the type previously constructed by the author. Having made himself familiar with the design limitations of the previous small models, the first major changes instigated by Hardman were to try to develop some means of steering other than by the ski, preferably by some means of metering the power in any proportion desired to each individual track.

Two different types of planatary gearing arrangements were tried. One of them had gear design defects, while the second had serious weight limitations as well as requiring excess efforts on the part of the operator. The third type of steering arrangement tried, was a clutch and brake assembly, similar to the type used in the caterpillar tractors. The first model using this type of arrangement had a multiple lead screw for the throw-out of the steering clutches. This type of throw-out assembly proved rather cumbersome and had a tendency to
gall up and make operation difficult. This fault was corrected by using a cam throw-out arrangement.

All of these three small snowmobile model constructed, had an air-cooled Harley Davidson engine, but of a smaller size than perviously used in the Eskelson Motor Sled. It was a forty-five cubic inch twenty-five horsepower engine. This engine had serious power limitations and again vibration problems were encountered with this type engine. This was the last attempt to use the V-type air-cooled engine. There are several air-cooled motorcycle engines which may be tried at some future date as they are vertical type twins which fire alternately. This exact alternate firing would eliminate the undesirable vibration characteristics of the V-twin engine.

The next machine constructed was a rather small two-man snowmobile using a clutch and brake arrangement for steering. A cam type arrangement was developed for the throw-out of the clutch, and engaging of the brakes on each individual track. This arrangement proved to be very satisfactory, and at present, this type vehicle seems to have very good possibilities. This vehicle was called the Frandee St. Bernard. (Figure 24.) It used the type of track assembly that drove from both ends of the track. This arrangement was different from the track used on the Eskelson Motor Sled. The Motor Sled track drove from rear wheels only, and used a larger wheel at the rear to give a slack loop at the top of the track which tended to increase the contact area. While satisfactory for the small machine, the Frandee method of driving the track had definite advantages.

The two Frandee St. Bernard models had serious operational limitations because of excessive weight. A redesign of this vehicle very probably could eliminate much of the weight; especially in the casting used
Fig. 24. Frandee Saint Bernard - Frandee Number 3 in the background
in the steering arrangement, differential assembly, etc., which were all of cast iron. These castings could be replaced with aluminum castings.

The engine used in these vehicles was a Hercules four-cylinder engine of sixty-one cubic inches displacement which gave only twenty-five horsepower. This engine is one that has been used because it was available, not because it was desirable. It is basically a stationary type of engine, and consequently it is much heavier in all casting than would be desirable in an over-snow vehicle.

The author firmly believes that any future snowmobiles that are built will definitely have to use components which are designed for use in snowmobiles, much the way components are designed for use in airplanes. The use of such components would eliminate most of the weight problems that snowmobile designers have to deal with, thereby reducing weight to maintain flotation in all types of snow conditions.
Early in the spring of 1954, an inquiry was received relative to snowmobiles by the Utah Scientific Research Foundation from the Western Electric Division of the Bell Telephone Company. The Western Electric Company had recently been commissioned by the government to take charge of installations of radar warning screens across the northern part of the western hemisphere as a means of giving warning to the United States from any attack from an aggressor which might come from across the Arctic area. The Western Electric people recognized that one of their most serious limitations to work in the far north Arctic region was the problem of transportation.

Most people have no real conception of the conditions in the far Arctic. They fail to realize that only approximately ten inches or precipitation falls each year in this area, and were it not for the extreme cold, the area would be a desert region. Because of this fact, extreme depth of snow is not the most serious problem in the Arctic. There are certain isolated regions in the near Arctic such as the interior of Alaska where great depths of snow accumulate. However, this is not true in most areas above the Arctic Circle.

The problem of typical Arctic terrain above the Arctic Circle is first, one of open water. Next serious to this is the pack-ice which reaches proportions hard for the average person to comprehend. In addition to this, in the summer months there is a melting and small pools and lakes of all sizes form on this ice. The water being anywhere from a few inches deep to several feet deep. These pools are
broken up by ridges of ice giving an enormous honeycomb effect. This ice condition is nearly impossible for any of the vehicles to traverse at that time.

In the areas where bare ground shows through during the short Arctic summer, other conditions develop such as the muskeg areas where there are great bogs of vegetation and mud. Most vehicles become hopelessly stuck under these conditions and have to be abandoned, and then they sink in deeper each year until they are consumed in the muskeg bogs. The other bare areas are composed of rough rocky areas. There is really no easy terrain of any type to traverse in the Arctic area.

Four snowmobiles of the Frandee Model E type were shipped into the Arctic area for use by Western Electric Company. They reported that the vehicles would go nearly anywhere, and because of their good flotation characteristics did not get stuck, but because of the rigid frame type of construction used on them, they were rapidly shaking themselves apart due to the rough terrain which produced severe vibrations in the vehicle. As that type of Frandee snowmobile seemed unpractical for that area and in as much as no other vehicle was commercially available, the Western Electric people contacted the Utah Scientific Research Foundation.

The Western Electric people asked the Utah Scientific Research Foundation to study the type of problem that exists in the Arctic and attempt to develop a vehicle which would meet the needs of the people having to travel in that area. Because of the extreme urgency on early installations of the radar warning network, extreme impetuous and importance was placed upon the development of this vehicle. Accordingly, Hardman and France were flown into the Arctic area where, for several weeks, they studied the conditions and watched the operation of previous
Fig. 25. Frandee Sea Wolf Model 1
over-snow vehicles sent into that area. They returned and construction was immediately begun on the type of vehicle, thought by them, best suited to meet the needs of the Western Electric people.

A desirable completion date for the pilot model of the large Arctic vehicle, which has since been named the Frandee Sea Wolf, was set for July 1954. Because of the many involved problems in the design of this vehicle, this date was not met. By September, the vehicle was ready for shipment to the north, and after a series of preliminary tests in the Logan area, where the vehicle was run on the bare ground, swamps, and open water, arrangements were made to fly the vehicle to the far north. (Figures 26, 27, 28.)

The vehicle was driven from Logan, Utah to Hill Field, Utah, where it was placed aboard a large transport airplane for delivery to the northern area. It can be noted here that the only practical means of transportation into this Arctic area at this time is by airplane. Everything is flown in from the food and necessary supplies to maintain the crews, to large pieces of construction equipment such as RD-8 Caterpillars.

Following are some of the construction characteristics of the first model Frandee Sea Wolf:

The engine used was a Continental engine of approximately eighty horsepower. This engine, having had its power increased without increasing the weight especially for this vehicle by the Continental Motors Company. The Continental Motors Corporation has been extremely cooperative in helping the Utah Scientific Research Foundation with any prime mover problems that they have had. This liaison work was under the direction of Mr. Earl C. Ginn, chief engineer, now vice-president in charge of quality at Continental Motors Company.
Fig. 26. Frandee Sea Wolf Model 1 - Vehicle is being driven by a water propeller
Fig. 27. Frandse Sea Wolf Model 1 climbing over a vertical drop-off.
Fig. 28. Frandee Sea Wolf Model 1 - Vehicle is being driven by both tracks and propeller.
The transmission was a four-speed Warner transmission, and the transfer case was a custom constructed unit. The case was made from cast aluminum and fitted with gears for the necessary drives to the front and rear track assemblies and to the propeller used for amphibious operation. The vehicle had two tracks in the front and two tracks in the rear. Each track was driven by two tires of about 6.00 x 16 size. The tires used were specially developed track type tires procured from a United States rubber company. The belt used in the tracks was a specially developed belting for use in extremely cold conditions which would maintain its flexibility in a minus seventy degrees F. below zero. This belting was produced specially for these vehicles by the Goodyear Tire and Rubber Company of Akron, Ohio.

The front and rear sets of tracks were driven independently by a drive shaft from the transfer case. Steering was accomplished by turning the front set of tires through use of a hydraulically boosted steering mechanism. The power to the tracks was transmitted in a manner that allowed the rear tracks to do the driving under most conditions to reduce the number of gears that were operated under power, thus eliminating some of the power loss through gears. There was an over-running clutch arrangement installed in the drive-line between the front and rear set of tracks which allowed the front tracks to immediately engage should any slippage be encountered by the rear set of tracks.

The vehicle was rather large and was designed as a combined personnel and cargo carrier. It was completely water tight up to a point which allowed it good flotation for amphibious operation, and a propeller and rudder assembly were installed for operation in deep water. When shipped to the Arctic region, the vehicle was accompanied by Hardman and Floyd Wilhelm, a foreman mechanic at the Utah Scientific Research
Foundation. They ran the vehicle through a series of tests in the Arctic area and found that some difficulty was experienced with the drive hub assemblies, as the wheel hubs had not been properly heat treated, resulting in a stripping of the keys from the wheel hubs.

After approximately two weeks in the Arctic area, Wilhelm became rather ill, probably from the drinking water conditions in that area, and, as his stomach did not seem to adjust itself to the environment, it was deemed wise for him to return to Logan. Hardman, however, stayed in the Arctic area for some time corresponding to the shops in Logan as to the difficulties encountered with the vehicles. He relayed, by wireless, instructions to the men working in the shops at Logan, and they immediately constructed new hubs and axle assemblies and shipped them by aircraft to the Arctic region. It should be noted here, that these men were working under severe limitations as they were depending only on limited radio instructions, and their previous knowledge of what went into the vehicle to make the necessary corrections. They did an excellent job, and the parts, when received and installed by Hardman, cured most of the difficulties of the vehicle. This further points up the author's point on testing. Had it not been for the fact that Hardman, being fully acquainted with the design and construction of the vehicle, had been on the ground where the actual testing was done, perhaps the vehicle would have been deemed as inadequate and not have been followed further. However, through Hardman's diligence in testing, the major problems were licked and the Western Electric Company indicated their acceptance of the vehicle as being the most promising of any that they had tested.

With the rapid approach of the Arctic winter, it became necessary for Hardman to return to the shops in Logan to begin preliminary pre-
parations for the next design of the Frandee Sea Wolf. Correspondence was received later from the Arctic area from the operators using the vehicle, who indicated that they had run approximately 1,000 miles over extremely difficult terrain with little or no difficulties.

During the early winter months of 1954, preliminary design problems were investigated for the construction of the next Frandee Sea Wolf with an attempt being made to cure some of the problems noted during testing of the first vehicle. Some of these being: the vehicle had to be made lighter, and the cost had to be reduced. These changes are being incorporated in the next machine.

The Utah Scientific Research Foundation engineers proceeded to make preliminary designs of components they felt should be included in the next vehicle, and in the meantime, negotiations were started with the Western Electric Company for a contract to supply another Arctic test vehicle. A contract was received in March 1955 by the Utah Scientific Research Foundation for several of these vehicles, and the first pilot model of this group is now being completed in the shops of the Utah Scientific Research Foundation at the time of this writing.

The first vehicle will be shipped to the Arctic area for lengthy testing of the several changes that have been incorporated. The first model was constructed mainly of a tubing, truss type structure. In the model now under construction an attempt is being made to use the monocoque type construction, and make the skin carry most of the load, much as is done in aircraft construction. Where it can be used, of course, this type of construction is the lightest for the size of the vehicle.

The shape of the hull has been changed to improve the amphibious characteristics and to reduce the propeller cavitation and rudder steering problems. The oscillating arms which carry the track have been
redesigned, making a stronger and lighter assembly for support of the wheels which the tracks run on. Heavier springs are being mounted for the suspension of the vehicle.

The author wishes to note that the unique springing arrangement of the tracks of this vehicle make it so that the cab remains relatively level while the tracks follow any uneven terrain encountered. Under most terrain conditions, this vehicle can overcome nearly any type of obstacle in its path; mud, swamps, rocks, etc., do not seriously hinder the vehicle.

All snowmobiles with which the author has had contact have had the serious limitation of being only snowmobiles and are relatively useless outside of the few months they are used during the winter. Such is not true of the Frandee Sea Wolf, as the tracks can be removed and the vehicle operated as an extremely versatile vehicle for bare ground conditions. During the early testing of the vehicle, the tracks were removed and the machine driven through several extremely rough mountainous areas with little or no road to follow, and the vehicle outperforms a Jeep very easily in most conditions while traveling through this rough area.
CHAPTER VIII

MILITARY SNOWMOBILES

Eliason Motor Toboggan

The Eliason Motor Toboggan was developed shortly before World War II. This development took place in Clintonville, Wisconsin. The machine is just as the name suggests, a motorized toboggan. This vehicle was constructed as light as possible and still provide transportation for two men. It consists of a wooden toboggan approximately twelve feet long, and three feet wide. (Figure 29.) A two-cylinder seventy-four cubic inch Indian Motorcycle engine is mounted toward the front of the toboggan and this engine drives an endless belt-type track about twelve inches wide, and six or seven feet long. The track runs in a slot through the toboggan and means is made to adjust the depth at which this track runs below the sliding surface of the toboggan.

This type vehicle was tried on snow survey work by the Soil Conservation Service in mountainous areas, and was determined to be relatively useless in the deep powdered snow found in this area. When traveling in three or four feet of powdered snow, the toboggan, the motor, and half of the operator is under snow. On relatively firm snow, the toboggan does a fair job; however, in the really soft conditions there is a tendency for the track to lose its grip and then the sliding surface of the toboggan supports the machine, causing the tracks to spin. It is high-centered, so to speak, with the track unable to gain any grip for forward motive use.

Considerable trouble was also experienced from over-heating of the air-cooled motorcycle engine. The engine also had the inherent
Fig. 29. Eliason Motor Toboggan
vibration problem as discussed earlier in this study. An attempt was made to assist the cooling of the engine by mounting an electric driven fan in front of the motor. However, this was not entirely satisfactory. The over-heating problem was caused by having to run the engine near top revolutions per minute in order to gain sufficient power for forward motion while the forward speed of the vehicle was relatively slow in difficult conditions. This slow speed under heavy pulling conditions did not provide enough circulation of air to maintain the proper operating temperature for the engine.

In certain areas of the country, where the snow is relatively firm and heavy, the Eliason Motor Toboggans have some utility, but in the mountain-west area, it is not a practical over-snow vehicle. This type snowmobile is still produced in limited numbers by the Four-Wheel Drive Automobile Company, who have purchased the manufacturing rights from the original Eliason Toboggan Company.

**T-27 Snowmobile**

In 1941, the Vehicle Development Branch of the Ordinance Department, United States Army, became interested in the development of a light over-snow vehicle. In investigating the vehicles available in the field, a decision was made to attempt the construction of a snowmobile based mainly on the principles used in the Eliason Motor Toboggan. Subsequently contracts were let with the Allis Chalmers Company for approximately six test vehicles of the type designated as T-27.

Before development work on the T-27 snowmobile began, the Vehicle Department center of the Ordinance Department listed some characteristics which they felt the completed snowmobile should have. They are as follows:

1. **Project Report.** Snow Tractor, T-27. Project Number: KG-231, p.8-9, October 1, 1945
Tests consisted of operation at Camp Hale, Colorado on varying conditions of snow, weather, operating personnel and tactics. No attempts were made to evaluate snow conditions by actual measurement since conditions vary so greatly from place to place, and hour to hour, that it was believed more desirable to design for the worst known conditions knowing that more favorable conditions would then offer little trouble. Studies of the mechanics of, and behavior of, each type vehicle in snow were made, and it was determined generally that:

a. Low center of gravity is essential.

b. The center of gravity should be displaced far enough forward to give reasonably constant ground pressure throughout the length of the track on extreme grades (30%).

c. Accomplishment of paragraph b. above can best be attained by a half track vehicle (skis on front and tracks on rear) since the high loadings at the front on level snow, due to displacement of the center of gravity forward, are carried on the skis.

d. Vehicles with skis in front provide much better steering characteristics in deep soft snow than full tracked vehicles.

e. A half track vehicle with skis on the front is not satisfactory for bare ground operation.

f. A full tracked vehicle could be provided with satisfactory steering characteristics if a differential were developed which would permit application of power to one track in a reverse direction to that of the other track, thus permitting instantaneous pivot turns.

g. Existing designs of controlled differentials cause speeding up of the outside track in making turns, thereby wiping the snow out from under that track. This results in banking in a direction opposite to that desired.

h. A unit ground pressure of 0.7 pounds per square inch is desirable.

i. A horsepower to weight ratio of 60 H.P. per ton is desirable and in many instances will permit "bulling" the vehicle through otherwise impassable places.

j. The space between tracks should be kept to a minimum consistent with good steering.

k. In cases where the space between tracks is greater than 1.40 times the width of one track, a ground clearance of at least 22 inches should be provided.
1. Waterproofing of the electrical system is essential.

m. Traps for water to accumulate in the fuel lines should be avoided.

n. Cold starting aids should be provided.

o. Light man-handleable vehicles are much more desirable than large machines. All snow vehicles require expert drivers and yet may become stuck daily. Light vehicles under these circumstances are much easier to extricate.

It can be noted that many of these desirable features listed, coincide with the experience found earlier by Soil Conservation Service, United States Geological Survey, Utah Scientific Research Foundation, and others in their snowmobile development program.

The T-27 snowmobile was relatively small, approximately nine feet in length and thirty-two inches in width. (Figure 30.) It was driven by an endless track. Twelve inch driving wheels were mounted on a forty-one inch wheel base for the track. There were no boggie wheel assemblies, but the track was depressed against the snow by means of a shoe arrangement which the tracks slid under. This shoe arrangement was not satisfactory because of high wear conditions, high friction, etc. The vehicle was steered by two separate skis approximately thirty-five inches long. These skis had a small fin on the bottom and were controlled by a large pair of handle bars, similar to motorcycle handle bars.

The power was supplied by a Waukesha Model 16K four-cylinder engine of approximately twenty-two horsepower. This engine is the same as one tried by the Utah Scientific Research Foundation, and is too heavy for proper use in a snowmobile.

Several of these vehicles were produced with slight variations in each of them. One model had the engine changed to a Harley Davidson
Fig. 30. T-27 Military Snowmobile - produced by Allis Chalmers Company
180 degree opposed type engine. Cooling problems were encountered with this air-cooled engine because of the high power output of the engine and low vehicle speed did not provide adequate cooling.

Several of these vehicles were tested at the Winter Testing Branch of the Ordinance Department, at Camp Hale Colorado, and also in the Mount Rainer, Mount Hood area. A vehicle of this type was also tested by the Soil Conservation Service about 1946, at Logan, Utah, under the direction of Clyde. These tests of the Soil Conservation Service were not satisfactory enough to warrant using the vehicle for snow survey use. The operational characteristics of the vehicle, climbing, side-hilling, etc., were not good and only a small amount of the power produced by the engine was transmitted to forward tractive force, as the track assemblies with their sliding guides were inefficient and consumed most of the power in frictional losses.

With the arrival of V-J Day in 1945, the project was stopped and no further work has been done on the development of this vehicle.

**M-7 Snowmobile**

The M-7 snowmobile was also developed by the Ordinance Department of the United States Army. In overall appearance and operational characteristics, it is very similar to the Barrett Snowmobile No. 3. (Figure 31.) It drove by a pair of tracks in the rear which ran on rather small bogie wheels, and was steered by means of a pair of skids in front and also by brakes which could be applied individually to the tracks to improve the steering characteristics.

Many of these vehicles have since been used by various public and private agencies which have procured the vehicles surplus from the army. They do a rather creditable job of over-snow transportation as regards performance, however, they are plagued with relatively frequent
break-downs. The chief problem is the failure of the bogie wheel system. The bogie wheels have a small rolling radius, and therefore subject the severe shock loads. In addition, the transmission and transfer case type of drive which is practically the same as used in a Jeep is somewhat overloaded in this vehicle. The power was supplied by an engine of Willys-Jeep design.

Most of the people operating these vehicles with whom the author has had contact, have felt that this vehicle showed some promise and would justify further investigation into the possibilities of this type vehicle. They all felt that most of the inherent mechanical difficulties could be eliminated by a little more engineering and especially by more thorough testing of the vehicle under actual snow conditions by the people responsible for the design.

The United States Forest Service has used many of these vehicles for its over-snow program in various areas throughout these western states and Alaska.

**T-36 Cargo Carrier Snowmobile**

This snow tractor was under the developmental control of the Vehicle Brance of the Ordinance Department of the United States Army, and was intended to function primarily as a tractor unit for towing a load of at least 1 1/2 tons on a sled-type toboggan behind the vehicle. It was a relatively large machine, weighing 5,000 pounds, with a crew of two men. (Figure 32.)

One of these vehicles was procured surplus in 1950 by the College. It was intended that this vehicle should be used by the Wild Life and Forestry Department for their operations in the mountains during the winter months. It proved very inadequate for this use. France, Devine, and the author had opportunity to make use of this vehicle as they saw
Fig. 32. T-36 Military Cargo Carrier Snow Tractor
fit for testing purposes. The vehicle was taken into the mountains several times, accompanied by some of the other snowmobiles, particularly the Barrett No. 3 machine, one of the small United States Geological Survey machines, and the Fransee SnoShu No. 1. In three or four feet of powdered snow, all machines would operate satisfactorily except the T-36. The T-36 would not operate in soft snow that exceeded more than about two feet. When the snow became deep enough so that it could not compress the snow and gain flotation against the ground, it immediately began to flounder.

It is noted from testing experience, that snow, after it becomes approximately four feet deep, is deep enough to force a vehicle to actually float on the snow rather than compress the snow against the ground. Snows above this depth present no added difficulty, that is, six or eight feet of soft snow is no more difficult to run in than four feet of soft snow.

The T-36, when procured from the Ordnance Department by the College, was in new condition showing approximately twenty miles on the speedometer, and the general appearance and fittings of the machine indicated it had seen little use. An attempt was made to lighten this vehicle as it was felt that the excessive weight was the factor causing the operational trouble, so everything that was not absolutely necessary for the running of the vehicle was removed. After this weight removal this machine still showed many bad characteristics. Success was never obtained in making this T-36 perform satisfactorily on the snow. In fact, it had difficulty in getting around, even on bare ground.

The track arrangement, which ran over broad track rollers, caused serious snow packing conditions. The final drive was by an open chain, which also presented serious difficulties as ice would build up on the
chain until the chains were in danger of breaking. It took enormous amounts of horsepower just to overcome the driving resistance of the chain and sprockets under these icing conditions. The bogie wheel system used on the vehicle was a series of rollers. These rollers were full width of the track which was approximately twenty-four inches wide. The snow packed between the track and the rollers as there was no provision for making the track self-cleaning, such as by the open center type of track used on the Frandee SnoShm and other snowmobiles. This condition led to excessive pressure being exerted on the bearing of the bogie wheels and even on the main drive wheel rollers. The bearings soon gave way and allowed the bogie wheel system to destroy itself.

The only feature which the author feels was really worth while and successful on this vehicle was the planetary type, gear box arrangement for steering the vehicle. The vehicle steered entirely by this planetary gear arrangement, and it seemed to function very well from a mechanical standpoint, but the vehicle was difficult to steer even with this arrangement because of the poor track. In the deep snow, it was completely unmanageable because of its excessive weight and poorly designed track.

By the time the vehicle had been tested to accumulate approximately forty miles; it was completely worn out. The tracks were jerky and the bogie wheel system was completely ruined because of bearing failure. The chains were severely stretched from icing conditions, and in general the life of this vehicle had been completely run through in forty miles. In the experience of the author, he had never seen a vehicle which had more features which showed less design experience in over-snow transportation.
Apparently this vehicle had been designed, as several others have been, with the people responsible for the design, having had no experience in actual over-snow transportation. That is, they have examined a few pictures of some previous machines, and studied a few patents, and then proceeded to design what they thought was a practical snowmobile. This type of designing always leads to difficulties in snowmobile construction, and there is no substitute for actual test experience in the elements concerned. Getting out in the deep soft snow of the mountaneous regions, or Arctic regions for long periods to become familiar with the varied snow conditions and climatic conditions that exist. Only about five of these T-36 vehicles were ever produced, and pursuance of experimentation was discontinued at the end of World War II.

**Army Weasel**

The Army Weasel tractor type vehicle is an amphibious full track type machine. It is meant to do the same job under amphibious conditions that the Jeep does on land conditions. In fact, it is built with several Jeep components being used. Most of these vehicles were constructed for the Army by Studebaker Corporation.

The Weasel is a full track vehicle, and steers by means of a planetary gear arrangement. It does a good job while it operates in the element for which it is designed, mainly that of rough muddy going and swampy water conditions, such as those found during the last war in the invasion of Holland and other low-lying lands of Europe.

For lack of a better vehicle for Arctic and other high mountainous conditions, the Army has proceeded to make wide spread use of the Weasel for its over-snow transportation. The vehicle is relatively heavy in relation to its flotational track area, weighing approximately
2.5 pounds per square inch of track area. It does a creditable job despite this serious limitation. The main defect the author has observed in operating and watching tests of the Weasel, was the failure of the track arrangement which used a bogie wheel system of small rolling radius with its attendant shock troubles.

The tracks tended to come off, particularly in the deep heavy snow conditions. When the vehicle attempted to turn, quite often the track would catch in the snow and the vehicle would roll right out of its tracks. This happened several times with the Weasles which worked on the Army plane crash east of Logan, Utah, in January of 1953.

Because of the availability of the Weasel in large numbers, the Weasel has been used more for snow transportation than perhaps any other vehicle. However, it has a long way from that which is desired in over-snow transportation.

**Otter**

The Otter, track type vehicle, of the Army, is a vehicle which was produced by General Motors, and designed intentionally as an over-snow vehicle or Arctic vehicle. It is also an amphibious type vehicle and at first appearance, one might think it was an over-grown Weasel which is true to some extent. The track arrangement on the Otter is better than that on the Weasel as it uses large tires, approximately 6.00 by 16 size and of a special type developed for track type vehicles by United States Rubber Company. The main limitation of the Otter is its heavy weight for the rather narrow track used. It may be satisfactory for some Arctic conditions where the snow is of a packing and hard type which will support good loads, but would be practically useless in the deep mountain snows of the western states.

These observations of the Otter, however, are second-handed
observations, the author having not had a chance to personally operate this vehicle. This vehicle is the only one included in this study of over-snow vehicles which the author has not had first-hand contact, so the observations could be wrong or prejudiced. However, they have been drawn from conclusions reached in the operations of other similar vehicles.
CHAPTER IX

TUCKER SNO CAT

The Tucker Sno Cats are the results of many years development and experiments in over-snow transportation. They are the invention of E. M. Tucker, formerly of California, and Medford, Oregon. Tucker's experience with over-snow transportation is probably as great as that of anyone in the field. He has produced one type vehicle or another for over-snow transportation since early in the 1930s.

The first snowmobile produced by Tucker, with which the author is familiar, is the Tucker Spiral Drive Snow Sled. This machine was built in the late 1930s and was a small vehicle supported by one front and two rear skis. (Figure 33.) The method of propulsion of the vehicle over snow was by a large metal screw which could be depressed into the snow. Under certain conditions the vehicle could obtain a speed of twenty miles per hour. This machine had some of the operational limitations of the Eliason Toboggan as it lost traction from screw slippage in soft snow, being left high and dry on its skis. Another serious drawback was the absolute limitation of the vehicle to snow, as it could not traverse any bare ground.

About 1940, Tucker Company, of Medford, Oregon, announced a type of snowmobile which has since been developed to an advanced stage. The first vehicle to go under the trade name of "Tucker Sno Cat," which is probably the most famous name in snowmobiles, were of the track-ski combination type. (Figure 34.) They steered by two skis in front and were driven by two endless link steel, type tracks. These endless tracks slid around an aluminum pontoon on rollers.
TUCKER SPIRAL-DRIVE SNOW SLED
DRUM CAN BE DEPRESSED IN SOFT SNOW TO OBTAIN GREATER TRACTION.

Fig. 33. Tucker Spiral-Drive Snow Sled
Fig. 34. Tucker Sno Cat two pontoon model
giving a nearly ideal method of traction and flotation; however, there are some drawbacks to this pontoon arrangement. In operation, the steel link track tends to wear and it is rather difficult to tighten it, but more seriously, the track is mounted on small roller bearings of approximately three inches in diameter. These bearings have an extremely high linear velocity when the vehicle is traveling fifteen to twenty miles per hour. These bearings also are continually immersed in the snow and in the late spring operation in mud and water which makes the condition even worse. The bearings are rather short lived and the difficulty of keeping them properly lubricated is also serious. No bearings could be procured commercially with shields good enough to meet the requirements for the Tucker Sno-Cat. Consequently, Mr. Tucker developed a seal, and produces in his shops, the seals for the bearings used on his vehicle.

The two pontoon Tucker Sno-Cat was produced in a variety of models and sizes. The largest of these was nicknamed by snow survey people, "The Tom Cat". This vehicle was an outstanding performer, especially in soft snow conditions.

After World War II, Tucker developed a four pontoon type snowmobile which steered by pivoting the front pontoons in one direction and the rear set of pontoons turning in the opposite direction, and so enabling this rather long vehicle to turn in a comparatively short distance. (Figure 35.) This four pontoon drive Tucker is probably the ultimate in performance in soft snow conditions of any of the vehicles available today. When this large machine is traveling with a light load, it will give an outstanding demonstration in snow of any type. The only thing that keeps the Tucker from being a completely successful snowmobile, is the problem of bearing failure on the tracks.
They require a large amount of maintenance in proportion to the time operated, and the problem of keeping them greased requires many man-hours of labor as each bearing must have a plug removed, a grease fitting inserted, and then this grease fitting taken out and the plug reinstalled after greasing. The grease fitting could not be left installed in the bearings as they would be too vulnerable and would be torn off during operation.

Should Tucker develop a method of improving the fault of this track and lengthening its life, he will undoubtedly have a firm hold on the snowmobile market.

It should be noted here that the Tucker Sno-Cat is by far the most widely used commercial snowmobile, and has been successfully operated in all parts of the western hemisphere where the snow transportation need exists. Most users of this vehicle like all of its features with the exception of the problem of track roller wear. Another factor which points up the success of the Tucker Sno-Cat is that the Tucker company has grown from practically nothing to its place as a prominent company. This growth being produced by nothing but the snowmobile market. The author knows of no other company which exists solely by the production of a snowmobile, with the exception of the Bombardier Company in Canada which produces a rather heavy snowmobile. This Bombardier snowmobile, however, is not satisfactory for use in the deep snows in the western mountains.
Numerous attempts have been made by various organizations, including the Utah State Agricultural College, and the Utah Scientific Research Foundation, to produce a successful small snowmobile. These efforts have been directed toward producing a snowmobile which would not gross over 1,000 pounds and preferably 500 to 700 pounds, thus making it possible to man-handle the machine and to transport it with a minimum of difficulty. None of the small vehicles produced have been very successful as yet. However, satisfactory results may be obtained in the future as several organizations are still working toward the development of these small machines.

Montana Snow Bug.

The Montana Snow Bug is a small snowmobile which has been produced experimentally at Montana State College by the people who conduct the snow surveys for that area. This vehicle was designed by Honson of the College staff at Montana State and assistance has been furnished by Ash Cod, snow survey leader for the Montana and Northern Wyoming areas.

Several models of this vehicle have been produced, and they are all basically the same, consisting of a wide toboggan type ski in front for steering, and a large pontoon with a track the full width of the vehicle revolving about it. (Figure 36.) This track is approximately three or four feet wide depending on the model. Power has been supplied by a rather small air-cooled engine. The present engine used is approximately twelve horsepower. This engine is coupled to a centrifical type clutch,
Fig. 36. Montana Sno Bug Number 1
and then to a small four-speed motorcycle transmission. The vehicle has been geared down to produce a rather slow speed. The people in that area are satisfied with four or five miles per hour, being more concerned with dependability than high top speed. This machine has, at times, demonstrated excellent climbing ability, because practically all of its bottom surface is a traction surface and under most snow conditions does an excellent job. The machine has been plagued with mechanical difficulties. These difficulties arise from two sources: first, the use of poor materials, and second, some times poor quality of workmanship in the construction of the vehicles.

Recently the latest model of the Montana Snow Bug has been completed and first test runs made. Some changes have been made to allow the track to run on small pneumatic wheels which should eliminate much of the friction, which was robbing the machine of most of its available horsepower. Nothing further can be said of the operation of the vehicle as it is just now undergoing its first tests. The author feels that the type vehicle these people are working on shows definite promise, but feels that much could be gained by improving the quality of the workmanship in the vehicles, and by also studying some of the more successful track designs used on other snowmobiles.

**Hobson Snow Traveler**

The Hobson Snow Traveler uses a full width track and also a full width toboggan type ski for steering. It has been produced in very limited quantities by a small organization in Montpelier, Idaho. (Figure 37.)

The author witnessed a demonstration of this vehicle in Sun Valley, Idaho, where it gave a very creditable performance climbing hills of about thirty percent. This vehicle has been used for snow survey work.
in the Montpellier, Idaho area, and has had fair success, however, it is definitely limited in its ability to operate on anything other than snow conditions as the toboggan, and especially the track, would be extremely vulnerable to anything except snow.

Power for this vehicle was supplied by a four-cylinder air-cooled Wisconsin engine. This engine, while heavy for snowmobiles, is nevertheless an extremely dependable engine, and produces its horsepower without overworking the engine. Also, it is one of the few air-cooled engines which has a really effective cooling system. A well designed squirrel cage type of blower supplies air to the cylinders and allows them to operate at full horsepower without overheating the engine.

Nelson Sno-Poke

The Nelson Sno-Poke was an experimental model developed by the Metalizing Company of Boise, Idaho. (Figure 38.) This vehicle consisted of a short pair of tracks which propelled the machine, and a pair of skis in front for steering. The framework was a bare skeleton of aircraft tubing with a seat for one person whose legs straddled the engine. It was a very small snowmobile, and though built extremely light, it did not have a very favorable flotation characteristic, exerting about three-fourths of a pound per square inch of track on the snow.

The author had opportunity to observe this Sno-Poke in operation in the Ketchum area of Idaho. In fairly heavy snow, the vehicle had great difficulty in making much progress because its weight was centered toward the rear and because its high ground pressure tended to make the machine dig in. The vehicle was constructed from parts which were not standard, even the engine was a small two-cylinder V-engine which had been procured from an aircraft type generator unit.
Fig. 38. Nelson Sno Poke
CHAPTER XI

PROPELLER DRIVEN SNOW PLANES

Of all the means of snow transportation, the propeller driven snow plane is the most spectacular to observe in operation. Many models of these have been built, including the type of propeller driven ice-boats used on the lakes of the midwestern states. At least three types have been produced in the western states, these being the Abacrombie Snow Plane, (Figure 39) produced at Jackson, Wyoming with a sixty-five horsepower engine; the Snow Cruiser, manufactured at Waitsburg, Washington; and the Call Air Snow Plane, produced by Call Aircraft Company at Afton, Wyoming. This last mentioned snow plane probably being the outstanding one manufactured today. The author has operated all three of these snow planes on occasion, and has owned one personally of the type produced by Abacrombie.

The propeller driven snow-plane is rather limited in the element in which it can be operated. It is used most advantageously in open country and in snow which is not too deep and powdery. In the areas in which it can be used, it far out performs any other type of over-snow transportation, and contrary to what most people believe, will even out perform them while climbing and sidehillling steep slopes. The author, in 1950, observed some comparative tests in which one of the Snow Cruiser Snow Planes was competing against several track type vehicles. This snow plane was able to consistently take a short run and progress up a sixty percent slope, turning and sidehillling and coming back down this slope. No other vehicle tested in the same conditions was able to climb above a thirty-seven percent point on the
The most serious limitation of the vehicle is while operating in dense timber country where the danger to the propeller might exist from hitting limbs and other projections. It is, of course, limited to snow and cannot operate on bare ground. This is a drawback as bare ground operation is very important to snow survey people as most of their work is done in the early spring. All models of these snow planes are extremely light. Some of them exerting a pressure on the snow surface of only one-fourth pound per square inch of ski area.

The Call Air Company of Afton, Wyoming, now produces a snow plane with an engine of 125 horsepower which is the ideal size for a snow plane. Less than this horsepower makes the snowplane sluggish in anything but favorable conditions. With the 125 horsepower engine, a good performance could be maintained under most snow conditions. The Call Air Company has also developed an excellent type of ski which is a composite structure made from sheet aluminum. It is extremely light and rigid, and yet is large enough to give excellent support to the snow plane.

It is often necessary, in order to prevent certain types of snow from sticking to the ski, to use a plastic base ski wax. Without this wax, the ski sometimes freezes down when the vehicle stops and it is nearly impossible to shake the skis loose from the snow or to loosen the frozen crystals of snow from the skis. This is particularly true in the early spring operation.

The large potential for the snow plane probably lies in the sporting aspect of over-snow transportation. The type of thrill given by the snow plane is different from any other experience a person has. At the present time, there are several organizations in the West Yellowstone Montana area, which have these snow planes and use them for trips
through the Yellowstone Park during mid-winter. This Yellowstone area is ideal for this type of operation as the fairly wide highways provide an excellent runway for the snow planes to travel during the winter. Also, these snow planes do not tend to pack the snow down too tightly as is the case with track type vehicles. This packing of the snow leads to difficulties when attempts are made to plow the roads out with the rotary type snow plow in the spring. This plowing problem has led park officials to be very reluctant to permit track type vehicles to do much running on the park roads during the winter period.
Fig. 40. Snowmobiles lined up for a speed test at Ketchum Idaho, February 1950.
CHAPTER XII

CONVERTED TRACTOR SNOW VEHICLES

Several companies have made an attempt to have their tractors used as over-snow vehicles. The most outstanding of these is the Cletrac company which produces a wide tread, track vehicle of very light weight. (Figure 41.) Several of these Cletrac vehicles accompanied Commander Byrd on his last pre-War expedition to the Antarctic area.

The Caterpillar company and others in the crawler tractor business, have sold units of their tractors to several organizations in the northern Canada country where these vehicles are used for towing tractor trains of supplies into isolated posts in Canada. These caterpillar type tractors have been successful in the area where the snow is not especially deep, and where there is hard wind packed type of snow which will support practically any weight of vehicle. Another factor in the favor of these tractor trains is, that they start relatively early in the winter and then tend to follow the same track on each trip, which tends to keep them a path very well packed down.

The use of these tractors in the mountaineous deep snow area, is practically useless as their ground pressure is too high to allow them to float on anything but the heaviest of snow. The Cletrac company has included a kit, whereby large two by four or two by six pieces of lumber could be bolted to the track and so increase the flotational area. However, the author's observation has been that when these vehicles attempted to travel in deep snow or especially in the grainy or powdery type of snow, they invariably dug in on the rear end and were able to make little or no progress in snow more than about \(2\frac{1}{2}\) feet deep.
Fig. 41. Oliver Cletrac with snow cleats installed on tracks.
This modified Cletrac makes an ideal vehicle for the rancher or farmer whose snow is not excessively deep, where he might use it for towing feed to his cattle, etc., but for real over-snow transportation in the mountains, it would not be satisfactory.

It is regrettable that few of the major crawler type tractor companies have never seen fit to tackle this over-snow transportation problem.
CHAPTER XIII

BOMBARDIER SNOWMOBILE

The Bombardier snowmobile is produced in large quantities in eastern Canada. It has been in use for several years and has found a wide acceptance, especially on the Great Plains of Manitoba, and Saskatchewan. It is especially adapted to areas where the snow has a chance to wind pack and assume a proportion of firmness. The Bombardier snowmobile is a large machine capable of hauling twelve people. (Figure 42.) The cab can also be fitted out to allow adequate, but cramped living quarters should the snowmobile be marooned in a storm or by breakdown. The Bombardier vehicle utilizes two long tracks and two short skis in front. The skis can be lifted or depressed hydraulically to improve their steering reaction on the snow. The tracks are driven from a sprocket at the front end and the tracks run around a series of large wheels instead of over small bogie wheels. This arrangement makes a very substantial track support system. When in their own element on the open plains of Canada, these vehicles will do an exceptional job. Especially outstanding is their speed. These vehicles now have obtained speeds of fifty miles per hour on snow, which is extremely fast for any type of snowmobile operation.

Operational tests have been run with the Bombardier snowmobile in the high mountain areas in the western states. The Bombardier has proven to have only limited success when confronted with several feet of soft snow. The Pacific Bell Telephone Company tried this vehicle in the Mount Rose, Nevada area, and Bakersfield California area for maintaining their micro wave relay stations. They found the vehicle inadequate for
their use in the deep mountain snows. The vehicle is well constructed and gives a person a feeling that much good design work has gone into this vehicle. It presents the finished appearance of a modern automobile.

The ability of this machine to operate so outstandingly on the plains of Canada and with limited success in the western mountains of the United States, points up the fact that it is extremely difficult for any one vehicle to meet the demands of the wide variety of snows and climatic conditions that are found in different parts of the world where snow falls. These varying conditions may very well be such a limiting factor that no one snowmobile may do the job, but rather it may be necessary to make a vehicle which is successful in a relatively narrow area and narrow varieties of snows.
CONCLUSION

Study of the many snowmobiles produced at Utah State Agricultural College, and by other agencies, shows definitely that it is not practical to design one type of machine to meet the many varied snow and climatic conditions. Vehicles for use in the Arctic areas will need to be heavier built and have an excellent spring suspension system to prevent failure of the vehicle from operation on rough terrain. An amphibious type of vehicle is also strongly recommended for Arctic use or it will have limited value during the summer months.

Snowmobiles for use in deep soft snows of the intermountain areas should be as light as possible and still maintain adequate strength. Independent track suspension should be excluded to save weight and to distribute the weight over as large an area as possible.

Full track vehicles require less horsepower to roll over the snow than do half track, ski guided vehicles, to slide over the snow, and in some operations, such as sidehilling, a lightly loaded finned type ski is desirable.

Overall vehicle weight should not exceed six-tenths of a pound per square inch of track area. This weight-area ratio if not exceeded assures satisfactory flotation in all types of snow.

Tracks should be relatively long in proportion to their width to reduce the frontal area and so lessen rolling resistance in deep snow. A vehicle length-width ratio of $1\frac{1}{2}$ to 1 should, however, not be exceeded or turning difficulties will be encountered.

The failure to produce a satisfactory snowmobile has been principally due to two factors. Most commercial organizations have failed
to recognize the many varied kinds of snow and have not designed to meet the most difficult conditions. These organizations have attempted to find substitutes for testing in actual field conditions.

The snowmobile program at Utah State Agricultural College has reached a point where a combined cooperative effort by all personnel concerned could produce a commercially practical snowmobile. The personnel of the Utah State Agricultural College, the Utah Scientific Research Foundation, and of other cooperating agencies have acquired a background in over-snow transport that is outstanding in the field, but there is definite need for a coordinating agency.

The failure of agencies and personnel concerned to cooperatively interchange design ideas and problems has been as formidable a barrier to the success of the Utah State Agricultural College snowmobile program as have been the tangible problems.

The Utah Scientific Research Foundation is gradually becoming the coordinating agency needed, and snowmobile models to meet both the Arctic and mountain problem seem imminent.
BIBLIOGRAPHY


APPENDIX
Tests of Frandee SnoShu

No. 4 in Oregon

By R. A. Work

Modification of Steering

Frandee SnoShu No. 4 Over-Snow Machine

As delivered by R. A. Work by the shops in Logan, Utah, this experimental model (No. 4) of the Frandee SnoShu was steered by a single all metal ski, wrist-pinned to an iron pipe 7'6" long. This pipe, in turn, was pinned to the frame of the machine by a horizontal shaft. The steering ski was mounted on a nearly vertical steering post at the extreme forward end of the steering arm. The ski was rotated in a horizontal plane by a worm and pinion steering shaft between the steering post and steering wheel in the cab of the machine.

The ski end of the Logan steering arm, as the original steering assembly is termed, was free to move in a vertical arc upward or downward, with its center of radius the horizontal pin at the front of the machine frame, but lateral movement of the ski end of the arm, as induced by steering the ski, forced the machine to follow around by leverage. The ski arm could only be raised manually from the snow. Similarly, the ski could only be forced deeper into the snow by addition of man-weight to the arm.

The Logan ski was all metal. Its keel was boat shaped; that is, it had a wide width 1½" at its base along the longitudinal axis of the ski, tapering to a narrow edge at either end and along its snow cutting edge. In hard snow this keel, because of its wedge shape, prevented the ski from sinking into the snow sufficiently for the flat surface of the ski to touch. This caused weavy steering due to the ski bouncing around on hard snow.

This type of ski and steering arm had certain disadvantages, or at least there were feature which could be modified at small cost to improve the operating performance of the machine, as well as the convenience and ease of steering, loading, and unloading.

The features which were modified were these:

(1) The Logan arm with attached ski had to be un-pinned from the machine and loaded somewhere into the bed of the mother truck each time the machine was loaded on the mother truck. It had to be pinned back again to the machine when unloaded from the mother truck. Since the arm and attached ski weighed 113 pounds and was awkward to handle, it was time consuming and difficult to take loose and reattach this arm each time the SnoShu was transported. The arm could not be allowed to remain on the machine in a vertical position, as in this position total clearance violated Oregon Highway Code (12.5 feet allowable total load height.)
The Utah arm depended upon its own weight to force the ski keel into contact with the snow surface tightly enough to give steering leverage to the machine. Supporting area of the Logan ski was 515 square inches. PSI of the ski normally loaded was 0.11. Consequently the steering arm was constructed in a heavier fashion than necessary from the standpoint of strength only. This extra weight very slightly increased PSI of the machine belt treads.

When running over bare ground, across logs or through stream channels, the machine operator either had to push the ski ahead of the machine over such surfaces manually to a vertical position and tie it to the machine in some fashion while passing over the obstruction. Pushing a ski through mud, rock or dirt is destructive of wax. Pushing a ski in cold weather through water usually results in instantaneous icing of the ski which destroys its freedom to slide easily over snow. There is no question of the importance of being able to quickly and easily raise the ski from contact with non-snow surfaces. This was a feature of Tucker Sno-Cats which the writer always felt could be improved, to do away with the necessity of jumping out to lower the wheels manually when crossing snow-bare surfaces then jumping out again to raise them.

The Logan ski, being all of steel, presented a surface to which snow adhered readily. Metal skis, unless of magnesium metal, do not slide as easily on snow as do hickory skis. This is particularly true of unwaxed metal surfaces on wet snow.

Changes Made

To avoid the above disadvantages, a new steering arm and ski were built at Medford. The Medford arm was shorter and lighter than the Logan arm. It was appreciated that shortening the arm would reduce the leverage available for moving the machine from straight ahead courses, but it appeared that if means were provided for forcing the ski into closest contact with the snow surface, the machine would necessarily have to follow the circuit of the steering ski. Seven-hundred miles experience showed this to be so. The Medford arm was built so it need not ever be detached from the machine; although it quickly can be. The arm is merely raised to a vertical position and fastened to the machine with a quick and positive clamp before loading the machine for transport on the mother truck. The Medford arm met Oregon Highway Clearance Code. One man can easily raise the Medford arm. The Medford arm and ski weights 92 pounds, about 20 percent less than the Logan arm and ski. PSI of the Medford ski mounted on the arm without pressure applied was 0.09, or 0.02 less than the Logan ski.

In order to force the ski into effective contact with the snow surface, a system of levers and cables operated from the cab provides means of instantly and easily applying pressure to the ski ranging up to 0.21 more PSI than was effective on the original Logan arm and ski without additional weighting. (Total possible PSI on Medford ski by cab levers...
Powerful twin springs in the lever and cable system provides a cushion effect and allows the ski to ride over any invisible object under the snow surface such as a log or rock. This springing effect makes the whole machine ride easier as it absorbs lurching when the machine tips forward into any deep hole in the snow. It also makes possible either increasing or decreasing PSI on the track treads, although, of course, it cannot affect total combined PSI of ski and tracks.

In order to lift the arm completely from the snow surface, a second lever arm inside the machine cab is used. This lever arm raises the ski a maximum of 2.5 feet above the snow surface. The ski is held in this position indefinitely, if desired, while the machine crosses logs, mucky or rocky ground, or water. A quick adjusting chain link hitch allows the operator to adjust this two foot clearance one way or the other to compensate for depth of sinkage into snow of the machine treads. The entire operation is controlled from within the cab. Total weight of the complete system of levers and cable is estimated at 22 pounds.

Finally a lighter, slightly smaller and extremely strong ski of steel ridged hickory was provided on the Medford arm. This ski holds wax longer than the metal ski and when bare of wax slides better on sticky wet snow than the all metal ski. The ski is a vulnerable point of this machine. Like a boxer's chin, it has to be strong. A finned keel was provided instead of a ship shaped keel as on the Logan ski.

The Medford control mechanism for raising, lowering, and applying pressure to the ski is mechanical. The same principle could be achieved more effectively in more workmanlike manner, and probably with less total addition of weight through use of a double acting hydraulic cylinder with safety valves. This was not done at Medford because of the lack of funds, but it is recommended for the next test model.

Narrative Account Over-Snow Travel for Test Purposes Frandee SnoShu No. 4, 1951
January 12; Observers: Work and Frost.

Snow was very soft and powdery but did not exceed thirty inches depth. SnoShu ascended Mount Ashland from Trail Camp in second and low gear, an ascent of 3,000 feet in five miles. Some difficulty was experienced on fifty feet of mild sidehillling due to the fact that not enough pressure could be applied to the steering ski to hold the nose of the machine up hill. It was intended to test the machine for climbing ability, sidehillling ability, turning radius, etc., in the relatively flat snow field near the summit of Mount Ashland. The machine reached this area and started the test when the front ski, being turned at a right angle to the horizontal axis of the machine to facilitate a sharp brake turn, struck a rock beneath the snow. The ski was knocked completely off the steering post. This was due to
a poor weld. It was impossible to test the machine further without this steering ski. Therefore, the steering boom was clamped in a vertical position and return trip to mother truck was made without difficulty through use of the differential steering brakes. Return trip took about forty-five minutes. The brakes became very hot. Total gasoline consumption was 2.7 gallons, equivalent to 3.7 miles per gallon.

January 20-21. Observers: Work and Dr. Harvey Woods

Following the trial run of January 12, some changes in the steering system were made. The machine was then driven to Lake-O-Woods, Oregon on January, and returned January 21. Snow was well packed. The machine sank only four to five inches most of the route. No steep climbing was encountered on this trip nor were any fallen trees encountered. Total mileage over snow was 76 miles. The machine averaged 8.3 miles per gallon of gasoline, carrying two passengers and a minimum of baggage. Snow samples taken at a newly established test area known as Machine Track No. 1, showed the machine was sinking 11.7 inches on snow with a total depth of 36.6 inches and density of 30 percent. On the return trip over packed track, considerable difficulty was experienced in holding the machine in the track made the previous day. This was due to inability to hold the single ski on the 18 inch snow ridge left between the tracks. This difficulty could be overcome by applying a great deal more weight to the ski or by using a steering system of dual skis spaced about twenty inches inside to inside. Dual skis are believed the best solution. It was also determined that the machine does not respond readily or positively to the differential brakes. Evidently the hydraulic cylinders are too small or the brake drum surfaces are too small or both. The difficulty seems not to be with the brake linings getting wet, as the brake action is equally difficult whether the linings have had an opportunity to gather moisture or not. The third criticism leveled at the machine as determined on this trip was the extreme amount of noise which evidently originates in the chain drive. Noise itself is a fatiguing factor and for this reason the machine is tiring to ride in many hours at a stretch.


The machine on this trip carried observers to all of the cloud seeding stations in or near the target area in Southern Oregon. On January 23, the machine traveled 44 miles in 5\(\frac{3}{4}\) hours running time (estimated) an average speed of eight miles per hour. This trip, for the most part, was made in very soft settling and sticky snow. On machine Track No. 1 course, the machine sank 12.2 inches on snow 5\(\frac{1}{2}\)6 inches deep with density of 38 percent. Density of the traction layer was undetermined. The snow was so wet and sticky that it built up inside the track and became so densely compacted as to result in considerable loss of power.
compacted snow adhering to metal parts bulged the track and made it as tight as a violin string. This loss of power became so great on one hill that it was necessary to dig the compacted snow out of the track with a shovel before the SnoShu could continue. In connection with the snow built up inside the rubber belt track, it should be pointed out that snow encountered on this trip was as bad as encountered on the West Coast. It was very soft with poor supporting power and yet of such high density so as to be very adhesive and capable of being packed into a mass as hard as concrete (figuratively speaking). On this trip several blown-down trees were encountered. Snow bridges were built across several such trees. In two instances it was necessary to cut trees. It was the opinion of both observers that this machine does not surmount fallen trees as quickly and as readily as the Sno-Cat. For one thing, before crossing a fallen tree one must take care to chop off any upright stubs of limbs which might otherwise puncture a tire. Furthermore, the machine does not secure such good traction with rubber-wood track in climbing over trees two or three feet in diameter as does the Sno-Cat with its sharp steel track. Some difficulty was experienced on this trip due to breakage of the head housing, the worm, and steering pinion. This breakage was due to the fact that the head had only been spot welded and not sufficiently strong for the use it has to take. By judicious use of bailing wire and an old stove poker borrowed out of a cabin, the damaged steering gear returned the machine safely to Medford. Gasoline consumption on this trip was 2 1/2 gallon per mile. (1/4 miles per gallon). Further trouble was pointed out by a fluctuating amp. meter, which was later determined to be due to a defective voltage regulator. A new voltage regulator was installed following this test run. It was noted that driving this machine was considerably more fatiguing than driving the Sno-Cat in comparable conditions. The machine was tiring for three reasons:

(1) Difficulty in effectively steering the Frandee machine; (2) noise and vibration originating from chain drive in the transfer case; (3) lack of springs between chassis and body. On the credit side of the ledger it should be noted that after leaving the mother truck on January 23 and before returning to it on January 24, snow melted off the road for a distance of 2 1/2 miles above the truck. Therefore, the Frandee ran on bare ground through mud and slush for 2 1/2 miles before reaching the truck. The machine operated just as speedily and as easily on this slush and mud as on the snow. This would not have been true with a SnoCat.


This was the first trip of the season in which the performance of Frandee No. 4 was compared directly with that of a Sno-Cat 433. Both machines started toward Diamond Lake on the Union Creek-Diamond Lake Highway. Each machine carried two passengers and a minimum of gear. Snow depth was about
Snow was granular with poor supporting power. Men without skis or snowshoes would sink nearly to the hips or in fact, almost to the ground. Within 100 yards after starting the run, in an effort to go around an obstacle across the road, the Frandee was driven off the shoulder of the highway and fell through soft snow at a steep lateral angle. In an effort to extricate the machine, the driver applied the same technique that would be applied to a Sno-Cat; that is, he rocked the machine to and fro to pack the snow, then attempted to pull out of the hole with a sudden burst of power. As the machine was rocked back and forth, without the occupants knowledge, the left hand track friction grousers climbed up into and then to the inside of the idler wheel and upon and partly inside the rear drive wheel. It was, of course, necessary to replace the track before the machine could progress further. No doubt some of the difficulty in removing and reinstalling the track to its proper position could be charged to the inexperience of the operators. However, due to the fact that the track was jammed and crinkled between the rear drive wheel and the body of the machine, it was a difficult job to remove and replace it properly. The procedure involved letting the air out of the tire and taking that wheel completely off, then pulling the track joining pin and getting the track to proper position before replacing the re-inflated tire. It required one hour and 55 minutes to restore the track.

There were many trees blown down across this route which could not be bypassed. It again was noted that the Frandee does not surmount such obstacles as surely and as quickly as the Sno-Cat. In crossing one very large log on a diagonal, just as the Frandee reached a balance point on the log, the machine unpredictable and instantaneously spun to a position parallel to and straddling the log. Fortunately the tracks of the Frandee are spaced so close together and the log was so large that the machine did not bracket and and hang up on the log. The driver was able to brake it to position for backing off the log. It was determined on this trip that increasing pressure on the steering ski by approximately 100 pounds resulted in much greater maneuverability of the machine. However, we still think this is not as good as twin skis.

An interesting experiment to compare towing capacity of these two machines was tried. The Sno-Cat, which weighed about 3,000 pounds, was very readily towed by the Frandee, but the Frandee, which weighs less than 3,000 pounds fully loaded, could not be towed by the Sno-Cat. The reason was obvious in that the Frandee tracks are wider than the Sno-Cat tracks, and, therefore, prepared a packed surface in which the Sno-Cat could travel. However, when the Sno-Cat attempted to tow the Frandee, the Sno-Cat tracks, being narrower, provided only a partially compacted track in which the Frandee could travel. That part of each Frandee track running in soft unbroken snow provided so much resistance to towage that the Sno-Cat's traction was not adequate, although the Sno-Cat's power was ample.
Total mileage traveled was 13 miles. Frandee gasoline consumption was 8.1 gallons, and Sno-Cat gasoline consumption was 10 gallons. Neither machine used any oil. The reason for this extremely high gasoline consumption on both machines for 13 miles travel is not readily explained, but engines were idled for hours while building snow bridges over big trees.

In connection with these tests, it was noted that the Frandee machine was more quickly unloaded and reloaded than was the Sno-Cat. The Sno-Cat treads sank deeper than the Frandee treads, to be expected, as Sno-Cat PSI is greater than Frandee.


The machine was taken on its regular weekly 80 mile cloud seeding run to Buck Lake, Lake-O-Woods, Fish Lake, and return. The operator was Less Marshall of Medford Irrigation District, accompanied by a United States Geological Survey representative who wanted to secure some stream gaging.

Marshall advised on return from the trip that he noticed oil leakage from the transfer case at each stop. Examination showed most of the oil leaking from around the head of the bolt which serves as pivot shaft for the idler sprocket arm. Marshall put four pounds of 90 W oil into the transfer case at Lake-O-Woods where a supply of gas and oil is cached for winter use.

He stated that he felt the Allen bolt and it fell off into his hands. Examination of this broken end showed crystallization of some age, as the break was rusty where the oldest.

The machine was driven slowly on the return trip, not to exceed eight miles per hour at any time to reduce the oil leakage to a minimum. The machine was put into the repair shop at Barnes Chevrolet, Medford, on February 8, in order to rout out the remainder of the broken Allen bolt and to attempt to put a gasket under the head of the bolt where oil leakage occurred.

Some oil leakage was also occurring from the transfer case due to leaky grease seals on the drive shaft but this seemed minor, so no effort was made to go into this repair at this time as the necessity was doubtful and the money wasn't available anyhow.

After Marshall returned from this 80 mile trip, we noted a large chunk of rubber gouged out of the right idler wheel tire. Beaumont ventured the opinion, which was proven correct, that the tire, carrying only 22 pounds of air pressure, was being pinched in rough snow between the steel track grabs and the wheel rim. It was concluded that tires should be inflated to 32 pounds hereafter rather than 22 pounds as recommended by Logan. Otherwise, we should eventually have no tires left. The damaged tire was replaced. (Note: As of April 1, no further tire damage has occurred. 32 pounds inflation answered this problem.

On this trip, Marshall ran over a pine knot about 1.5
inches diameter and 8 inches long which had fallen from a tree into the route and imbedded in the snow in a vertical position. This knot punctured a jagged hole in the track belt and then stuck right there, perhaps for miles, until the driver happened to see it at a routine measuring stop. Had this knot penetrated a tire instead of the belt it doubtless would have damaged the tire just as easily as the belt. Moral seems to be that freakish tire punctures could occur on seemingly smooth snow, even more easily than when crossing a log where the driver obviously would be on the lookout for damaging projections.

The machine now has been driven over snow 345 miles. Average gas consumption has been \( \frac{1}{8} \) gallon per mile, or \( \frac{1}{4} \) miles per gallon.


The machine was taken to Crater Lake to test competitively against the Tucker 4 Pontoon Sno-Cat. David and Goliath, so as to speak.

The snow was wind crusted, frozen, and supported both machines without appreciable sinking. Traction was superb. The Frandee demonstrated its superiority in speed and bare ground travel, but could not climb quite such steep grades as the Tucker 4 Pontoon. This was not due to loss of traction, but was due to failure of the Frandee power plant to develop enough power. The Frandee stalled on a slow winding climb of about 50 percent grade in the timber, but the tracks did not spin. When the Frandee could get a running start at short steep pitches, it went up a few 60 percent short climbs, but could not lug up long sustained, very steep grades, as could the Tucker 4 Pontoon.

Now, of course, elevation ate power. The tests were made at 7,000 feet elevation. The 73 H.P. Willys engine in the Frandee would deliver more power if the chain drive ratio were slightly reduced. Top speed of the machine is rarely utilised anyhow, in either high or intermediate gear. Gearing the chain drive reduction from 2.1 to 2.5:1 would increase power \( \frac{1}{3} \) and reduce speed \( \frac{1}{2} \). The advantages of increased power applied through this change would offset any possible disadvantage through loss of speed. Gearing reduction would be better than trying to use a more powerful and perhaps heavier engine.

This little Willys Hurricane engine runs like a clock, starts easily, runs cool, is easy on oil, and fairly easy on gas. It is a great engine for this machine and could hardly be improved.


The Frandee and the Medford Sno-Cat were driven to Lake-O-The-Woods to compare performance and to secure snow samples at several widely separated locations for spectroscopic analysis for silver iodide.
Each machine carried three men and their sleeping bags, skis, personal belongings and food. The load was equally distributed between the machines.

Snow at the beginning of the journey was packed road-way hard. Light snow began falling. New snow on old amounted to about one inch by end of the first day's journey at Lake-O-The-Woods. By mid-day of the second day, on the return trip, maximum depth of new fallen powder snow was six inches at the summit of the Cascades. Air temperature at sunrise the second day was 12 degrees F.

Both machines operated satisfactorily and without difficulty of any description. Each man drove each machine several miles under varying conditions of terrain and snow cover.

Due to the hard packed snow, the Frandee, lacking springs, was very hard riding and uncomfortable. All members of the party commented on the greater comfort of the Sno-Cat ride on hard snow. Conversely, most party members agreed that the Frandee was easier to steer on gently winding forest roads, but in crossing downed timber was less positive than the Sno-Cat in getting across such obstacles.

The Frandee proved slightly the faster of the two machines, by about two or three miles per hour, with both running at normal cruising speed.

Total distance traveled by each machine was sixty miles. Neither machine used any oil, but Frandee leaked 2½ pounds of 90 W from chain transfer case. All leakage seems to be around the drive shaft from transmission to the transfer case. Evidently the grease seal is "shot". Frandee's gas consumption was 9.1 gallons or 6.6 miles per gallon.

There was general, but not complete, concurrence among the party on the following changes that would improve the Frandee:

1. Either silence the chain drive or substitute for the chain drive a conventional Willys-Jeep transfer case. All concurred.

2. Substitution of Willys Transfer case would make available lower gears for crossing obstacles or for steep climbing. All concurred.

3. Mount the Frandee body on springs. The test model is dead axle and very rough riding. Vibration is so excessive that crystallization of a few welds on body members has occurred. All concurred.

4. Steering could be improved by adoption of twin skis and mounted closer to the tracks than the single ski on this test model. A hydraulic pump and cylinder should provide means of applying pressure to the skis or lifting them from the snow as required. A springing system, as now used on this pilot machine, should be a part of the hydraulic lifter-depressor. This would provide resiliency to skis and make the machine easier riding and less apt to lurch in going over logs and snow ridges. Not all concurred.

5. An improved differential braking system is needed as the present brakes require too much man-muscle to operate. All concurred.

The Frandee test machine No. 1 has now operated nearly
but not under such wide range of poor snow conditions as sometimes occur in Oregon. However, the 500 miles of operation has been sufficient to convince the writer that this machine is exceptionally meritorious and will undoubtedly warrant wide spread use in snow surveys after a few minor changes have been made.

Some comments by two members of the party follow:

Harold Thomas, District Ranger, U. S. Forest Service Ashland, Oregon: "To improve SnoShu, increase power and provide a better top and wind shield. If I were to choose an over-snow machine, I would take the SnoShu."

Ben Lombard, Attorney, Ashland, Oregon: "I would not now be able to decide whether Sno-Cat or SnoShu is the better machine. Here are some of my ideas on the SnoShu:"

1. As constructed, cab is dangerous; offers no protection.
2. Controls could be better arranged to afford more room and easier access.
3. Visibility could be improved.
4. Track controls work hard and there should be a locking brake.
5. I personally liked the single ski and think it is adequate."

February 27. Observers: Beaumont and Cory. (Narrative by Beaumont.)

The round trip distance over snow to Windigo Pass is 28 miles. The machine was unloaded along side Willamette Highway which is kept clear of snow during the winter. The snow depth here was approximately 45 inches including six inches of fresh snow.

After five miles, we came to a railroad crossing. The tension on the steering boom was released. Then, using the chain and the lever inside the cab, the steering ski was lifted approximately 2½ feet off the ground. After crossing the first set of rails, the machine lurched forward with such emphasis that it jiggled the pin loose from the chain which held the ski-boom off the ground. The ski then fell, hitting the ground with the ski turned sidewise and jammed against the outer railroad track of the second set of tracks. This bend the two inch pipe housing the steering mechanism of the ski so much that we were unable to turn the ski. The boom was, therefore, lifted up to the position in which it is carried when the Frandee machine is loaded for travel. With the boom in this position, trip to Windigo Pass Snow Course (elevation 5,710) was continued. Steering was accomplished by using the hand brakes. The last three miles of the route into Windigo is through a forest of large trees. Many deep snow pockets on either side of the road sometimes extend well into the center of the road. It is necessary for the machine to travel through these pockets. This occurs frequently in the last three miles of the route. Whenever one of these pockets could not be avoided, the machine was driven into the pocket, then turned either right or left
so that the front of the machine pointed straight up the opposite side of the pocket. We would then shift into low gear and climb out of the pocket. It was necessary to shovel a path into some of these pockets as the brakes did not give sufficient control to steer an accurate course. However, traction in climbing in or out was excellent and shoveling was necessary only because we did not have control over the steering. The depth of these pockets ranged from three to six feet and diameter ranged from 15 to 18 feet, sometimes with a tree in the center of the pocket.

At the top of Windigo Pass, the machine sank approximately 10 inches. Snow depth here was approximately 120 inches. Depth of new snow was 18 inches.

The return trip from Windigo was uneventful except for the same difficulty with snow pockets as encountered on the way in. Eight 6/10 gallons of gasoline was used. Miles per gallon, 3.2.

Total elapsed time for the entire trip to Windigo was 8½ hours. Two and one half hours were required to sample the course. Travel time would have been considerably less had not the ski steering mechanism been broken, resulting in steering difficulties.

March 3. Observers: Beaumont and Cory. (Narrative by Beaumont.)

The bent steering post was repaired at Bend, Oregon, prior to this trip. The machine was unloaded at Crescent Lake townsite approximately 12½ miles from the snow course at Summit Lake. Total snow depth at Crescent Lake was about 60 inches including 18 inches of fine, loose snow at the surface. No difficulty was encountered in vertically climbing out of the plowed road. A minimum amount of shoveling was necessary. The first six miles of the trip was uneventful as the road followed the west shore of the lake with very even grade and no appreciable increase of snow depth. However, after the sixth or seventh mile, steep climbing began. This long hill is so steep that only a pickup truck in lowest gear can ascend it in the summer.

The Frandee with three passengers including the driver loaded so that it weighed between 3,100 and 3,200 pounds, climbed this hill without any difficulty at all. Low gear was used throughout the climb. The machine sank approximately fourteen inches in the loose snow. A man without the aid of snowshoes sank into his knees in this loose snow. There was some evidence of the track slipping in the snow, but at no time did forward motion of the machine cease. During this prolonged climb the engine did not indicate a temperature higher than 160 degrees. The route into Summit Lake continues along a forest road which again has many large trees alongside it which resulted in large interception pits. There are also many steep pitches and up-grades after the prolonged hill is climbed, some of these with a grade of at least forty percent to forty-five percent.

At all times during the ascent of these grades and travel-
ing through the numerous pits encountered, traction was sufficient. However, it is felt that additional power would have been helpful several times. This additional power could be secured by gearing the machine a little lower.

Particular attention and care must be used when side hills are encountered. The whole machine has a tendency to slide to the lower part of the hill. The steering sky may be used as a support provided the snow is not too soft. This is accomplished by keeping the machine higher than the ski on the hill and then turning the ski so that the front of it points up the hill, thus resulting in a support for the entire machine. If the passenger in the right seat will then hold the uphill brake, the machine may be negotiated across the face of a side hill in a sideward motion.

At one time during the trip the canvas covering on the cab was punctured by a branch. It is recommended that passengers riding in the rear of the cab be warned of this possibility. A metal cab would be better, of course. During this trip, the machine sank to the upper top of the track in some places where drifts were encountered. Snow filled the inside of the track so as to completely blanket the wheels. The only evidence of snow packing on the track was in the metal cleats where the tires ride. It became necessary to know this snow and ice off occasionally. The efficiency of the ski in steering the machine when soft snow is encountered is reduced as the ski may be turned sideways and has very little effect if any on turning the machine. The ski was completely out of sight much of the time, and the steering post was only visible from the top supporting bar of the arm truss.

Difficulty in steering the machine was encountered because of lack of visibility. A fine snow spray from the track continuously blow over the whole machine, obscuring the view through the windshield. It became necessary for the driver to steer with his head out of the window. An adequate system of swipes and heaters are necessary to correct this difficulty.

Elapsed time on this trip (24 miles over snow) was exactly five hours. With one hour taken to measure the snow course, travel time was four hours. Gas consumption on this trip was six gallons, i.e., 6 miles per hour speed, four miles per gallon gas consumption.

Snow fell during the entire time. On the return trip the machine track in the snow was filled with fresh snow. There was no appreciable difficulty in driving the machine home in the broken track or in fresh snow. It is the writer's opinion (Beaumont) that the model 423 Sno-Cat would not have successfully completed this trip due to soft snow.

The following design changes would increase the efficiency of the machine:

1) A more adequate braking system to give more positive control. It is felt that this could be accomplished by increasing the brake drum surface and perhaps
using a larger hydraulic cylinder. One possibility may be
to connect these cylinders to a spring load steering system.
This braking system then could be used to steer. (2) As
mentioned before, changes to insure better visibility through
the windshield is also necessary. (3) It is also felt that
the cab could be improved for better comfort of the passengers.
(4) A fuel gauge would enable more convenient operation.

March 7. Observers: Beaumont and Perry. (Narrative by
Beaumont.)

Combined over-snow mileage on these two trips was 37 miles.
Gasoline consumption was 11.2 gallons. Nothing unusual was
encountered during either of these trips except a test was
made to see how steep a hill the machine could climb. A
slope of approximately 45 percent was negotiated with no dif-
ficulty. Snow depth here was about 30 inches, with about
10 inches of fresh snow. A man on the snow, unsupported by
snow shoes, sank about 18 inches. After the machine climbed
to the top of this hill, it was necessary to hold both
brakes in order to keep the machine from sliding backwards.
The machine was backed straight down the hill again by using
the brakes. At any position on this hill, the machine could
be stopped and started uphill again.

It is the writer's opinion that a Sno-Cat would not have
been able to climb this hill. In other respects, the
writer of this chapter compares the Frandee and Tucker 423
Sno-Cat as follows:

1. Traction of the Frandee is believed to be very
   appreciably greater than that of Sno-Cat under soft snow
   conditions such as these.

2. The Frandee under all conditions is faster than
   the Sno-Cat.

3. Because of the Sno-Cat's springs and motion of its
   pontoons, the Sno-Cat under hard snow conditions, is much
   more comfortable machine to ride in.

4. Control of the Frandee on sidehills is more secure
   than the Sno-Cat. There is less tendency for the front end
   of the machine to slide downhill as occurs with the ski
   models of the Sno-Cat. The entire weight of the Frandee is
   borne on the driving tracks, whereas the Sno-Cat, the
   front skis support a considerable amount of the weight. The
   Frandee negotiates and climbs over hardened snow banks much
   easier and with less hand digging than the Sno-Cat. Thus,
   it is the considered opinion of this driver that if a few
   minor changes and one or two main ones be incorporated in
   the Frandee to make it more comfortable for the passengers,
   to improve the braking system and to make it steer better,
   then this would be a better machine for snow surveys with
   less upkeep than the Sno-Cats.

This ends Beaumont’s narrative.

Accompanying Mr. Beaumont on two of these trips was
H.N. Cory, District Forest Ranger, United States Forest
Service, Crescent, Oregon.

On March 15, Mr. Cory wrote to Beaumont as follows:
"I have gone over your form for comparing the two over-snow machines. As you will note, I am inclined to favor the SnoShu and believe by the time it has been used to the extent the Sno-Cat has been used, it will be a very superior machine. On the form, I noted larger brakes should be installed and elimination of the tiller sid so steering would all be done differentially. Perhaps a couple of steering clutches could be incorporated to get away from the heavy power drain when making tight turns and to reduce wear on the steering brakes.

The comfort item can also be brought into focus for a little discussion. Chief objection is the lack of foot room, making a long trip tiresome for legs, especially ankles. The flat floorboard also contributes to foot discomfort. It would help a great deal to incline the forward portion of the floorboard in a manner similar to an automobile. This criticism can also be applied to the Sno-Cat.

Visibility is good but could be improved by elimination of the vertical posts and relocating the windshield wipers to cover the portion of the center section of the windshield normally used for forward vision. It would be desirable to extend the cab forward to a point about half way along the engine compartment if engine accessibility could be maintained.

From the foregoing comments it might seem that there is very little good about the SnoShu. I feel, though, that the track principle is right and that the designers have only to work out the minor difficulties and a very practical machine can be developed.

I would suggest the tool list include a clamp for tightening the track to the point where the splicing pin can be inserted should it be necessary to replace a track in the field. Also, a high lift jack such as the "Handy Man" could possibly be included.

The cab as constructed appears to be rather inadequate. There are times after a heavy snow storm, when the snow falls from the trees in great gobs. It is questionable whether the cab would withstand the shock of a direct hit from one of these gobs of snow. Also, the left door is too narrow, making it difficult to get into and out of the driver's compartment.

Finally the speed ratio between the engine and the tracks should be changed to allow slower ground speeds, and give better performance in tight spots.

In my opinion, this machine is the most practical one I have yet seen. The track assembly should be far less expensive to install and maintain than the complicated track and pontoon system used by the Sno-Cat."

On another of Beaumont's trips, he was accompanied by A. E. Perry, Watermaster of Deschutes County. Perry is a 23-year snow surveyor with lots of Sno-Cat, M-7, and propeller job experience.

Perry said "if I were to buy a machine for snow surveys, this SnoShu, if improved, would suit me."

He made the following suggestions to improve the SnoShu:

1. Turn the front axle over so drive is on one side, when the other side is locked so it will steer with brakes and do away with ski.
2. Mount cab on springs for easier riding.
3. Square up front of cab and take out glass and put automobile wind-shield glass in. (narrower)
4. Hinge doors from front and have glass tops—two pieces that slide sideways.
5. Use small hydraulic cylinders for braking effort. (use pump and two two-way valves)
6. Use a larger chain sprocket on the drive shaft, which will reduce speed a little and give more power for hard pulls and drive easier on hard snow that is rough."

Following Beaumont's return from this trip, Work noticed a damaged bearing on the main drive shaft into transfer case. It was fortunate that Beaumont got back to headquarters without the machine breaking down.

The entire transfer case was removed, and following contacts with the Logan office, air expressed to Logan for extensive repairs. The full nature of repairs can best be reported by Ross Eskelson. It consisted of line boring all shaft holes in the transfer case and installing new bearings and tightening the case against leaks.


The job was test-hopped to be sure it was in shape for extended snow survey travel, following the extensive repairs to the transfer case, noted above.

The machine was driven over snow and mud 12 miles round-trip to Hyatt Prairie Snow Course. Snow was badly melted out. The machine crossed bare ground, water, and some mud holes at least 100 times. Round trip took 65 minutes. It would have taken not less than four hours by Sno-Cat due to mud. The SnoShu worked fine and evidently is ready to turn over to Nelson for Idaho tests. However, the ride was extraordinarily rough and left no doubt in the minds of the operator and passenger that this outfit must be improved with springs between chassis and body to cut down on vibration and crystallization of metal welds, not to mention discomfort.

March 27. Observer: Beaumont. (Narrative by Beaumont)

Air temperature at start of trip was well below freezing. The snow pack was hard frozen. Snow depth at the starting point of this trip to Windigo Pass was about 40 inches with a density of 40 percent. Two passengers and normal equipment were carried on this trip. Travel began in high gear with an indicated speed of about twenty miles per hour. It soon became apparent that this speed could not be maintained due to the excessive vibration of the machine. The snow surface was extremely rough from uneven melting. Each frozen rib or raised portion of the snow acted as a "curbstone", resulting in excessive jarring even though these ribs, in some cases, were no more than three or four inches above the snow surface. Speed was reduced to three or four miles per hour to help prevent the
vibration. Low gear operation was necessary for the entire fourteen mile trip to Windigo Pass and part of the way back until air temperature rose sufficiently to soften the top layer of the snow. Excessive vibration broke the windows of the machine and loosened many body screws and bolts. It appeared, also, that the peculiar operation of the three unit voltage regulator is due to this vibration. Two new voltage regulators have been installed on this machine. On installing, they checked out alright, but after a short period of operation, became subject to "ticking" and constant jumping of ammeter from full charge to zero while the machine is not in motion. The battery is also noticed to be leaking fluid out of the top. This is not believed due to "boiling" the battery. The engine, since the beginning, has been extremely easy at all times to start. The battery, leaking is believed due to excessive machine vibration in hard snow.

March 30. Observers: Beaumont and Nelson. (Narrative by Beaumont)

Steering mechanism of the machine failed. The vertical shaft that connects the ski with the wormgear at the top of the steering boom crystallized. Inspection revealed that it had been cracked for some time. It is believed that the excessive vibration may have been responsible for this.

It is therefore imperative that the body be separated from the chassis, by adequate springs, so as to add comfort and durability to this machine.

Conclusions and Recommendations. (Joint by Work and Beaumont)

1. The braking system requires improvement. This is probably the most important requirement for improving this machine to the point where it can go into standard production for snow survey use. Differential clutches as well as brakes, bigger brake drums, better lining, perhaps means for smoothly applying greater pressure, are some of the things to be considered. The brakes work against the engine in this test model.

2. Dual skis rather than single ski should be provided spaced about 20 inches inside to inside so as to run in track marks on old trail. The skis should be on a shorter arm than on the present model, and this arm should be hydraulically raised or depressed by cab control. This system should be designed to allow variable pressure on the skis, but with safety releases. The twin skis should individually have not less than 350 square inches surface and the keels of each not less than 80 square inches surface, or depth less than 3 inches. Each ski should be on an inclined kingpin so as to tip the ski sideways on turns, thus increasing the keel fin effect.
3. The body of the machine should be mounted on springs and redesigned so that there is only one full width shatter-proof truck windshield. Metal cab should be provided. Canvas cab is not desirable. Comfortable bucket seats are needed. Adequate hot water car heater, electric swipes and defrosters are absolutely essential.

4. Power-speed ratio should be reduced to provide more power at expense of speed, if necessary. If a Willys Jeep transfer case be provided instead of present chain drive, speed could be retained but more power would be available when needed.

5. All voltage regulators on this machine's wooden dash should be grounded, otherwise the regulators burn out. It cost us two regulators to find this out.

6. Every effort should be made to reduce noise. Substitution of a Willys transfer case for the present chain transfer case, we think, would help, as most of the noise seems to telegraph through the machine from the chain drive. Costs must be held down and we appreciate the chain transfer as a means to this end, but the excessive noise is distracting and tiring.

7. The Medford Frandee lost its track only once but that once was annoying. We incline to the opinion that the steel track wheel grabs could be made one inch deeper. This would tend to prevent the track from coming off. It might slightly increase friction, but if the extra inch on the grab was flared out a little, increased friction would be negligible.

8. Tires should run at 32 pounds pressure. The use of six ply tires would be desirable.

9. The track shows no appreciable signs of wear or abuse, nor do the tires after 765 miles travel. However, the hickory cleats are showing a little scouring, but would be good for two or three thousand more miles. If Ross will impregnate these cleats in the future with boiled linseed oil mixed with turpentine (for penetration) it will harden the wood and they will last indefinitely.

10. The Willys Hurricane Power plant is ideal. This little engine starts in the coldest weather and runs like a clock.

11. The track tightening arrangement is very ingenious and has worked perfectly. No comments other than to suggest some simple means of determining if track tension is the same on both tracks. We just guess at it now, but perhaps this isn't especially important, anyhow.

12. Finally, if the above recommendations be engineered
into future models for further testing, the writer is convinced that this Frandee will be superior to any other machine now known for snow survey use. The designers and builders have performed snow surveys a good turn and are entitled to full commendation.