# Articulated Tracked Vehicles

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*There has been a significant revival of interest in articulated tracked vehicles and during the past few years several have been built in the United States and Canada. The following article reviews their development and discusses the principal features of this interesting but little known type of vehicle.*

DURING the fifty-odd years of their development, all but a few tracked vehicles have been built with two laterally rigid tracks. In consequence, they have been steered by creating a difference between the thrust generated by each track at the ground and thereby obtaining a turning moment which slews the tracks and turns the vehicle. Mechanisms devised for this purpose have been described in several articles[1, 2, 3, 4] and they have undoubtedly reached a high degree of refinement. But, in essence, steering by track slewing remains rather crude because of the way in which tracks have to be skidded over the ground, and it continues to impose serious limitations on the design and performance of tracked vehicles.

One major consequence of laterally rigid tracks and the associated skid-steering methods is that they confine the configuration of tracked vehicles within relatively narrow limits of the ratio of length to width, or, more precisely, of the ratio of the length of track in contact with the ground to the distance between the centre lines of the tracks. For serviceable vehicles this ratio must lie within the narrow range of 1·0 :1 to about 1·8 :1, because of the magnitude of the resistance to track slewing in relation to the maximum longitudinal thrust which a track can generate. As a result, tracked vehicles can not assume a longer and narrower form, which would be more advantageous for cross-country movement,[5] and the larger models are condemned to higher ground contact pressures than those possible with small vehicles, because weight increases as the cube of the linear dimension whereas ground contact area increases only as the square. Moreover, with the existing vehicles, when the soil under the track is stressed close to failure, the slewing moment necessary for steering can only be obtained by reducing the thrust of one track, since it is not possible to increase that of the other. Thus, steering is accompanied by a reduction in the total forward thrust and in soft soil may lead to complete immobilisation of the vehicle, as described in an earlier article.[6]

To overcome the shortcomings of laterally rigid tracks and skid-steering, a few attempts have been made to produce steering by track setting, but the difficulties associated with the laterally flexible tracks which are necessary and the complication of the track setting mechanisms have worked against the adoption of this method. It is interesting to note that these developments may be traced as far back as 1897, when the U.S. Patent No. 12,447 was taken out for J. A. Justice and P. Johnson, of Macey, Arkansas.[7] Curved track steering was also devised, apparently independently, in Australia by L. E. de Mole and embodied in the tracked armoured vehicle design which he unsuccessfully submitted to the War Office in 1912.[8] Yet another apparently independent attempt was made in this country in 1921 by Lt.-Colonel P. Johnson with his Light Infantry Tank. This amphibious vehicle was capable of speeds of up to 30 m.p.h. and thus represented a startling advance on the first generation of tanks built during the 1914–18 war but its laterally flexible "snake tracks" with lubricated spherical joints proved troublesome.[9] What is more, its development was not allowed to proceed very far as it was abandoned, together with Colonel Johnson's other designs, when the first Tank Design Department was closed down in 1923, in one of the government's periodic economy campaigns.

No further attempt to employ curved track steering appears to have been made until the 'thirties. In 1934, N. Straussler designed in this country a light turretless armoured vehicle which attempted to exploit the lateral flexibility of a conventional dry-pin track to provide a limited degree of steering by track setting; the track was bowed by having the two inside road wheels, out of the four on each side, mounted on vertically hinged arms. The vehicle was built in 1935, by the Manfred Weiss Company, in Hungary, where a second, turreted armoured vehicle with a similar track assembly was subsequently made, but Straussler himself abandoned the provision for track setting almost immediately after the construction of the first vehicle and his later design embodied laterally rigid tracks each driven by a separate engine.

At about the same time, Vickers-Armstrongs, Ltd., also adopted a limited degree of track setting on the Bren Gun Carrier, this being accomplished by lateral displacement of one bogie on each side. In 1936, this was followed by the design of a light tank to the A.17 specification in which Vickers Armstrongs incorporated a complete system of track setting by pivoting all four road wheels on each side of the vehicle. This vehicle, successively designated the Mark VII Light Tank and the "Tetrarch," saw limited service during the 1939–45 war[10] and, together with its later war-time derivatives, the "Harry Hopkins" airborne light tank and the "Alecto" self-propelled gun, still represents the most successful example of curved track steering.

To illustrate the performance of this type of vehicle, the "Alecto," which weighed 17,600 lb and was about 13ft 6in long overall without the gun, had a turning radius of 49ft using track curving alone. This was accomplished with a conventional type of track, laterally flexible to the extent permitted by the clearances between the track pins and the holes in the track links. The reduction of power losses by curved track steering was reflected in the good overall fuel economy of the vehicle but for tight turns it still had to use skid-steering and the additional complication of the track setting mechanism has not been considered justifiable in more recent designs.

Instead, there has been a revival of interest in articulated vehicles, whose manner of steering may be regarded as an approximation to curved track steering and which can dispense with skid-steering mechanisms altogether. Thus, while curved track steering involves bowing the whole length of the track in contact with the ground, the turning of articulated vehicles involves, in essence, disposing two or more laterally rigid tracks so that their centre lines are at an angle to each other and thereby approximating to curving of laterally flexible tracks. In general, articulated vehicles have been built with two units, each unit having two tracks like a conventional tracked vehicle, but a "bellyless" type with only one track for each unit is also feasible and one of the latest experiments involves three units, each having two tracks.

The idea of steering tracked vehicles by articulation appears to have originated later than curved track steering but the development of this type of vehicle began earlier. The first articulated tracked vehicle was designed in this country by B. J. Diplock

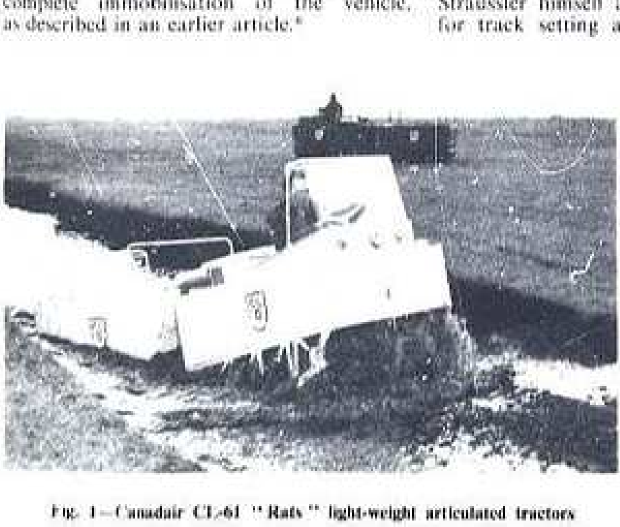

Fig. 1—Canadair CL-61 "Rats" light-weight articulated tractors

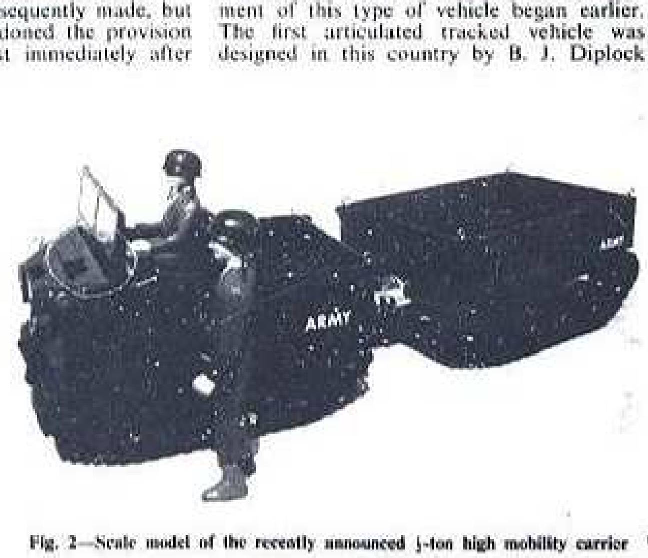


Fig. 2—Scale model of the recently announced ½-ton high mobility carrier CL-91

around 1912 and was exhibited at the 1913 Commercial Motor Vehicle Exhibition at Olympia, in London. It was fully described on these pages at the time[11] and additional information on this and Diplock's other designs was subsequently given in the series of anonymous articles on the evolution of tracked vehicles published in THE ENGINEER in 1917,[12] which are worth mentioning since recent writers on the subject are obviously hazy about the early developments.

Diplock's original vehicle consisted of two units, each having two tracks, but only the front unit was powered. The two units were hinged by means of a joint with a pivot and guide, which allowed the two to roll relative to each other, and steering was accomplished by turning the rear unit relative to the front, or, to quote from page 99 of the July 25, 1913, issue, "by using this vehicle after the fashion of a rudder." The actual steering mechanism consisted of a worm mounted horizontally in the front unit and operated by the driver and a mating worm wheel sector on the rear unit. How it performed does not appear to have been recorded but Diplock's idea of an articulated tracked vehicle was taken up in 1915 by Colonel R. E. Crompton, who was engaged to design the first tracked "landships" and who proposed that they should be articulated. To explore this possibility a series of tests was carried out in July 1915 with two agricultural tracked tractors coupled together but this combination proved impracticable, particularly when it came to crossing trenches. It is not clear whether any attempt was made in this case to steer by articulation or whether Crompton's proposed "landship" was to be steered in this way in addition to being articulated. An even earlier "landship" design, in which Diplock had a hand, also had four tracks but apparently it had a rigid chassis and was meant to be steered by driving the tracks on each side at different speeds, i.e. by track slewing.[13] The same appears to have been the case with the only practical outcome of Crompton's "landship" work, a four-track experimental chassis with a rigid frame built in 1915, using Diplock's "Pedrail" tracks, which proved a failure.[14]

Nothing further was done about articulated tracked vehicles during the next thirty years, except for a small model experimented with by British forces in India during the early 'thirties.[15] One or two experiments were also carried out in Germany, France and Britain with trucks having their wheels replaced by tracks but, although the resulting four-track vehicles steered in a manner somewhat similar to that of articulated vehicles, they hardly belong to the same category.

Interest in articulated tracked vehicles did not revive until the late 'forties, when it sprung from two entirely different sources: one was the empirical development of special-purpose vehicles for operation in snow and the other was theoretical studies of soil-vehicle mechanics.

The first produced the "Sno-Cat" built around 1949, in the United States, by Tucker on the basis of the accumulated experience with several half-track-and-half-ski machines devised during the 1939–45 war. It was introduced successfully for public utilities maintenance work in the Rocky Mountains and subsequently attempts were made to adapt it to military purposes but these proved abortive, for reasons which had nothing to do with the basic idea. Four "Sno-Cats" were also used by the 1957–58 British Trans-Antarctic Expedition and have already been described in connection with the latter.[16] In essence, it was a vehicle with a laden weight of 8,400 lb, four powered tracks and "four wheel" wagon steer.[9] Because of its exceptionally large surface contact area in relation to its weight, it had a nominal ground pressure of only 0·7 to 0·9 lb per square inch and this, combined with steering by articulation, produced a significant advance in performance over snow.

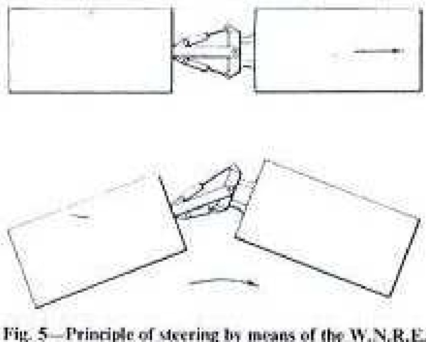

Fig. 5—Principle of steering by means of the W.N.R.E. "Polecat" type train joint

The second source of interest in articulated tracked vehicles was provided by M. G. Bekker, who advocated their development around 1948, while working on vehicle mobility in Canada, and during 1950–51 carried out a series of small-scale model tests in the United States at the Stevens Institute of Technology.[17] Later Bekker's ideas prompted the development by the Canadian Directorate of Vehicle Development of a small "bellyless" articulated carrier, the "Rat." The original model, evolved during 1955–56, proved highly mobile in snow and further development was undertaken by Canadair Limited, of Montreal. The Canadair version, designated the CL-61 Light Weight Articulated Snow Tractor, is shown in Fig. 1. It was designed in 1956 and the prototypes were tested in the winter of 1957. Of the six vehicles initially ordered by the Canadian Army, four had integral aluminium bodies and the other two had tubular steel chassis and glass fibre reinforced plastic bodies.[18] Subsequent models have had chassis frames consisting of a grid work of rectangular steel tubing and a water tight body of riveted aluminium sheet, the body and chassis forming an integral structural member. Under the influence of military air drop requirements, the chassis and engine mountings were designed using a load factor of 12g, which proved entirely adequate since subsequent parachute drops on a special platform showed that deceleration on impact never exceeded this figure.

The two units of the "Rat" are connected by a simple coupling on the centre line of the vehicle, below floor level, but the amount of relative angular movement in the three principal planes is restricted by two hydraulic dampers which splay out in a horizontal "V" from a single mounting on the front unit to the rear unit. Steering is accomplished by a cable and pulley arrangement, a drum at the bottom of a steering column taking in the cable on one side of the vehicle and paying it out on the other, which pulls in the rear corner of the front unit towards the corresponding front corner of the rear unit and thus alters the angle of articulation between them. The total angular movement in the horizontal plane is 80 deg. and the turning radius is about 9ft for an overall vehicle length of 14ft 6in.

In contrast to the original Directorate of Vehicle Development test vehicle, which had an engine in each of the two units, the "Rat" has a single 35 b.h.p. Volkswagen

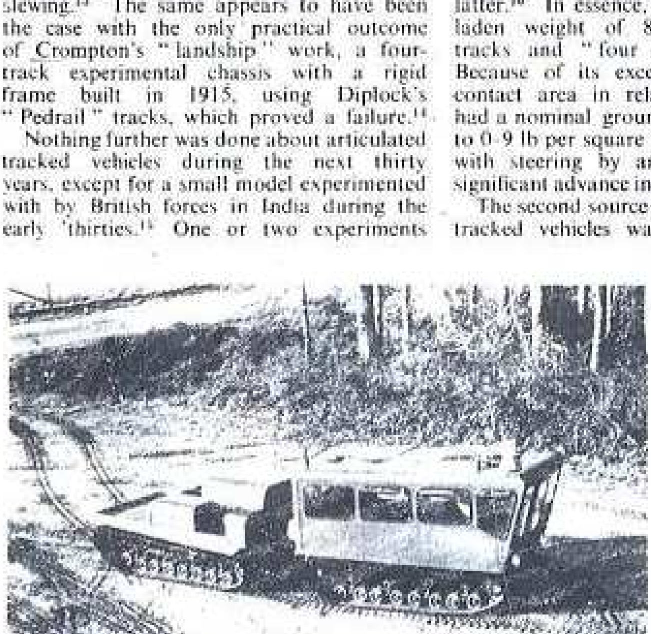

Fig. 3—Original model of the "Polecat" built by Wilson, Nuttall, Raimond Engineers in 1957

Fig. 4—Model 941 of the W.N.R.E. "Polecat" built for personnel transport in Greenland

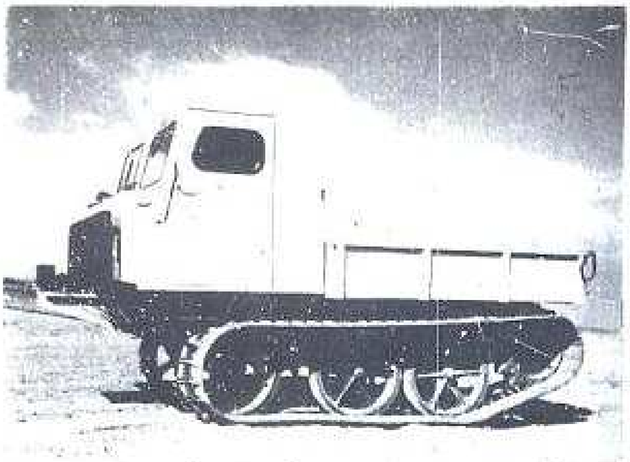

Fig. 6—Current model of the Nodwell "Scout" carrier

RN-21B

engine, mounted in the front unit, which drives all four tracks. Each track is made up of three conveyor-type rubber belts with connecting metal cross-bars or grousers and the tracks take up practically the whole of the vehicle width, so that the "Rat" is "bellyless." This arrangement has reduced the nominal ground pressure to such an extent that at the maximum gross weight of 2,000 lb it is only 0·5 lb per square inch, or, in other words, about the same as that exerted by an average man on skis. The "Rat" has a maximum speed of 25 m.p.h. but in practice this is restricted by the absence of springing, other than that provided by the resilience of its pneumatic-tyred road wheels. It can also float in water and propel itself at up to about 3 m.p.h. by means of its tracks.

Since 1957 Canadair "Rats" have been successfully tested in the Canadian North, Alaska, Antarctic and several other parts of the world. During the course of their trials they have successfully negotiated swamps, tundra and muskeg, as well as snow-covered terrain, and have proved useful as light cargo carriers under the extremes of winter and summer conditions.

The performance of the "Rat" has recently led to the development of a similar model for the U.S. Army. This is the ½-ton High Mobility Carrier, or CL-91, a model of which is shown in Fig. 2. The new vehicle is being designed and built by Canadair under the terms of a development sharing programme between the Canadian and U.S. Armies. Initially seven prototypes are to be delivered to the U.S. Army and three more will be built by Canadair for its own test purposes. As its American designation indicates, the CL-91 is to have a payload of about half a ton, and it is to be powered by a 65 b.h.p. Chevrolet "Corvair" engine located in the front unit. If desired, the front unit can operate independently of the rear section and the vehicle is expected to have a maximum speed of 30 m.p.h. on hard level ground but it is intended principally for use in difficult terrain.

Another line of development was started in the United States by Wilson, Nuttall, Raimond Engineers, Inc., of Chestertown, Maryland. The president of this company, C. J. Nuttall, had been with Bekker at the Stevens Institute of Technology and the company built its first articulated vehicle in 1957. This, called the "Polecat" and shown in Fig. 3, was based on a conversion of two "Weasel" carriers. These carriers were designed in 1942 in response to a U.S. Army requirement for a light cargo carrier capable of operating on snow and were used extensively during and since the latter part of the 1939–45 war, both in the standard M29 version and converted into the M29C amphibious carrier. Both had endless rubber-belt tracks and the M29, which weighed 4,925 lb laden, produced a nominal ground pressure of 2·1 lb per square inch. Most of the "Weasel" components were retained in combining two of them into the "Polecat" but a single engine, located in the rear unit, powered all four tracks, the drive to the front unit being taken by standard universally-jointed shafts through the centre of the connecting and steering joint. The design, of the train-type,[8] allowed complete freedom between the two units in roll and pitch but motion in the steering plane was at all times under full hydraulic servo control, and the manner of steering with this type of joint is shown diagrammatically in Fig. 5.

Tests with the "Polecat" in snow showed that it performed better than the parent vehicle and thus vindicated the concept of a two-unit tracked vehicle steered by articulation. In particular, the "Polecat" produced a drawbar pull 230 to 240 per cent that of the "Weasel" and was able to maintain speed in deep snow even while manoeuvring, whereas comparable skid-steered vehicles, which could compete with it when going straight ahead, lost headway and frequently became immobilised when turning. As a result of this encouraging experience, a redesigned "Polecat" was introduced by the U.S. Army in 1959 for high-speed personnel transport in Greenland and vehicles of this type have been used there with success ever since. They have demonstrated not only that their greater length leads to a better ride but also that, in spite of a 40 to 50 per cent increase in the average operating speed and a 20 to 25 per cent increase in unit weight, the life of tracks and suspension components is longer than in the parent skid-steered "Weasel."

The personnel carrier version of the "Polecat" is shown in Fig. 4. Its front unit, on the left, houses an International Harvester BD-264-6 6-cylinder engine of 122 b.h.p. net at 3,000 r.p.m. and a five speed synchromesh transmission, and provides seating for the driver and radio operator; the rear unit provides seating for six passengers. At full load the front unit weighs 6,600 lb. and the rear 7,000 lb, the corresponding nominal ground pressures being 2·1 and 2·2 lb per square inch, while maximum speed is given as 20 m.p.h. The overall width is 6ft 9in and length 26ft 5in but, in spite of this, the turning radius is 19ft.

While Wilson, Nuttall and Raimond Engineers, or W.N.R.E., were developing the "Polecat" for operation on snow, another company, the Robin-Nodwell Mfg., Ltd., of Calgary, Alberta, began to build a two-unit tracked vehicle for use by the Canadian oil industry in muskeg areas during the summer seasons, which had not been practicable with vehicles of any weight. It was not an articulated vehicle in the full sense of the word but consisted of a tractor, called the "Scout," and a companion separately powered trailer. However, the two units derived some advantage from each other and the whole combination emphasised the need to depart from conventional single unit tracked vehicle designs for successful operation in organic terrain, such as the Canadian muskeg.

The current version of the "Scout," the RN-21B, is shown in Fig. 6. It differs from the original RN-21 in having a strengthened frame and running gear, and wheels with solid rubber, instead of pneumatic, tyres—a surprising change in view of the general trend in this class of vehicles and the use of pneumatic tyres on other Nodwell models. However, in common with other vehicles, the "Scout" has wide continuous rubber belt tracks and a low nominal ground pressure, of 1·8 lb per square inch at the gross weight of 9,000 lb, but it also has one feature peculiar to Nodwell designs, namely rubber toothed driving sprockets.

Muskeg experience prior to the appearance of articulated vehicles has shown that, using nominal ground pressure as a rough index of performance, vehicles giving more than about 5 lb per square inch generally cut through the muskeg with their tracks and become immobilised. Vehicles with

Fig. 7—Nodwell RN-200 "Transporter"

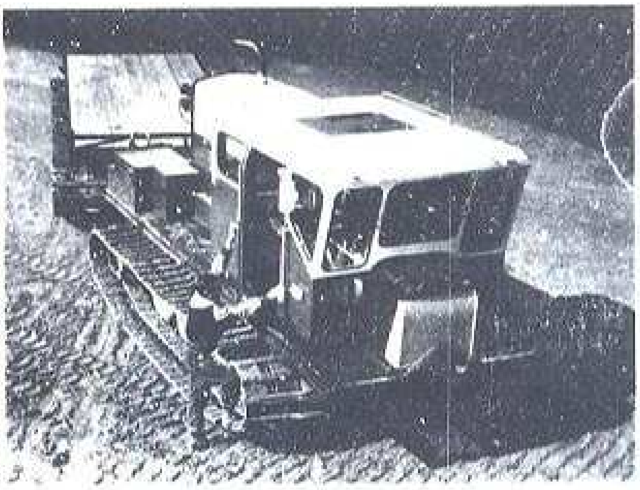

Fig. 8—W.N.R.E. "Musk-Ox" of 90,000 lb gross weight, the heaviest articulated tracked vehicle to date

ground pressures between 5 and 2½ lb per square inch have been able to operate in some cases over carefully picked routes but it is only when ground pressures are below 2½ lb per square inch that vehicles can operate with relative ease. Light special-purpose vehicles have been built, of course, with ground pressures of only about 2 lb per square inch, as shown by the U.S. Army's "Weasel" and the much more recent and successful amphibious M76 (originally T46E1) "Otter," built by the General Motors Corporation. But such low pressures can not be achieved with heavy vehicles of conventional design without resorting to impossibly wide tracks. In consequence, ground pressures of all but the lightest conventional vehicles remain relatively high. For instance, the lighter armoured vehicles average about 7 lb per square inch while battle tanks produce up to about 13 lb per square inch. Thus, to design heavy load carriers with ground pressures sufficiently low for muskeg operation it is necessary to adopt articulated construction, which makes it possible to keep the pressure low by increasing the total track length while track width remains within practical limits.

In consequence, the introduction of the original Nodwell "Scout" combination was followed by the construction of several articulated vehicles for muskeg operation. In 1957, for instance, Imperial Oil, Ltd., built an experimental articulated vehicle, called the "Centipede," by coupling two of the Nodwell powered trailers by means of a W.N.R.E. joint similar to that used on the "Polecat." The resulting twin-engined load carrier was rated at 5 to 6 short tons payload, compared with 2 to 4 short tons carried by the original Nodwell "Scout" combination, and its performance in summer muskeg operation was such that in 1958 Imperial Oil, Ltd., ordered another and even larger articulated vehicle from W.N.R.E., the "Musk-Ox."

In the meantime, the Robin-Nodwell Mfg., Ltd., introduced yet another articulated vehicle for muskeg operation, the RN-200, which was put into service by the Shell Oil Company of Canada Ltd., in 1958. This large "Transporter," shown in Fig. 7, weighs 34,000 lb and can carry a payload of 20,000 lb but due to its four 48in wide tracks its nominal ground pressure is only 1·9 lb per square inch at the gross weight of 54,000 lb. All four tracks are powered, the front two by an engine located under the cab and the rear two by a second engine mounted at the front of the load platform. Originally two 292c.in. Ford V-8 engines were used but these have now been replaced by GM 4-53 diesels, which are used with Allison "Transmatic" torque converter transmissions, giving the vehicle a maximum speed of about 10 m.p.h. Other features of interest include the tracks, each of which consists of two special 18in wide five-ply belts of nylon and cotton bonded with a rubber cover and cross bars of steel. The belts have proved very durable and the original set was used for three years without a failure. Track driving sprockets are of the Nodwell rubber tooth type and the road wheels have 7·50×20 pneumatic tyres: although the current specification still calls for steel cord tyres experience with several different types has proved that nylon and rayon tyres give the longest life and presumably these will be specified in the future. What is perhaps most interesting, however, is the method of steering, which is of the wagon type.[4] The front cab and track unit rotates under hydraulic control in the steering plane and is also free to pitch and roll in relation to the platform while the rear track unit is only allowed relative movement in the vertical plane. There are two hydraulic steering cylinders mounted under the platform and connected to the turntable of the front unit by heavy cables. With this arrangement the vehicle has a turning radius of about 25ft for an overall length of 39ft and a width of 10ft.

Three RN-200 "Transporters" have been used by the Shell Oil Company for three successive summer seasons to move drilling equipment and supplies across muskeg country. In the course of this they have successfully traversed all types of muskeg, with the exception of the "floating bog" variety with loosely consolidated peat covered with grassy vegetation and usually with water at the surface. In addition, the "Transporters" have traversed gravel bars and rock strewn areas and continued to be used successfully for a time after freeze up, until more conventional vehicles could take over. The transition period, with alternate freezing and thawing, proved to be the most difficult because of ice build-up on frames and running gear, and after freeze-up rough and rutted sections of the trail, frozen solid, were liable to cut the track belts rapidly.

The W.N.R.E. "Musk-Ox," which was built in 1959 and which is shown in Fig. 8, is the largest articulated vehicle so far. Its gross weight is 90,000 lb, out of which 28,000 lb are accounted for by the front unit and the remainder by the rear unit, which carries the whole of the 40,000 lb payload. The overall width of each is 10ft and the overall length of the whole vehicle is 48ft 7in, but for shipment the two units may be separated. The front unit, which carries a 375 b.h.p. Cummins NRTO-6 turbo-charged diesel and which has independently controlled brakes at the sprockets, can be run and manoeuvred on its own but the rear unit is dead when disconnected from the front unit. Normally the vehicle is steered by hydraulic actuation of the W.N.R.E. train joint by means of two Vickers cylinders of 6in diameter and 21in stroke, and the turning radius is 42ft.

In view of its weight, it is of some interest to observe that each track of the "Musk-Ox" consists of four nylon-rayon fabric belts covered with rubber, each belt being 8in wide and 1in thick, and has cast manganese steel shoes and magnesium backing plates. With conventional skid-steered tracked vehicles continuous rubber band type tracks are generally confined to much lighter vehicles. The overall width of each track is 52in and this results in a nominal ground pressure of 2·5 lb per square inch for the front unit and 3·4 lb per square inch for the rear unit, which is remarkably low considering the gross vehicle weight. The suspension is also of some interest as it consists of two walking beams on each side of the front unit and three on the rear unit, each beam carrying one trailing and one leading arm with a pneumatic tyred road

Fig. 9—"Cobra," the first three-unit articulated vehicle WNRE

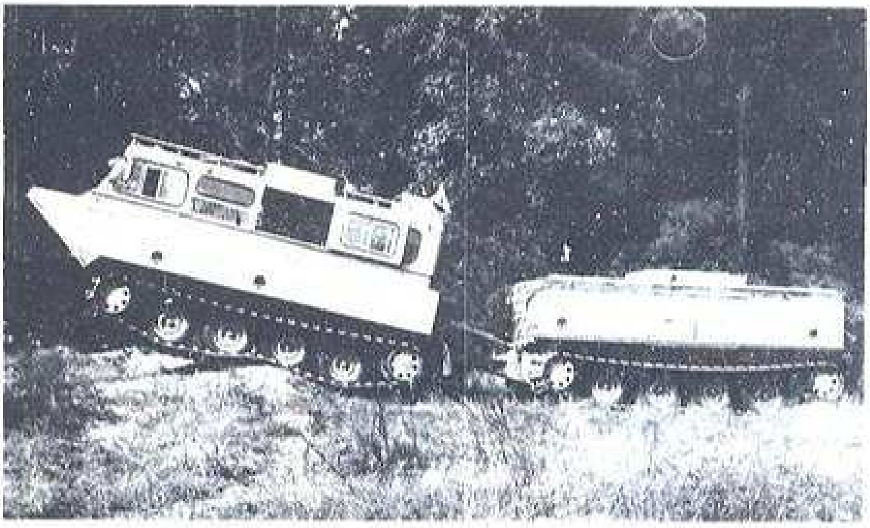

Fig. 10—Dynamometer-prototype of the "Terrapin" amphibious articulated vehicle WNRE

wheel. The smooth twenty-ply 9·00–15 nylon tyres are operated at an inflation pressure of 120 lb per square inch and this also happens to be the operating pressure of the General Tire 14in air pillows by means of which the road wheels are sprung and which are located between the arms and the walking beams. The air springs on both units are interconnected and there are levelling valves at the first, third and fifth bogie on each side, while other valves at the second and fourth bogies average the pressure between the two adjacent bogies on the same side. The combined effect of this type of suspension and the overall length of the vehicle is to produce a comfortable ride even over relatively rough terrain and the "Musk-Ox" is geared to a maximum speed of approximately 14 m.p.h. Altogether, the "Musk-Ox" is an exceptional vehicle, not least, perhaps, for the fact that in the first two summer seasons of difficult muskeg operation it successfully logged 13,000 miles. Some of the operational background and the early experience with the vehicle have already been described elsewhere.[19].

Three other articulated vehicles have been built more recently by Wilson, Nuttall, Raimond Engineers, each showing novel or different features. One is the "Cobra" three-unit articulated vehicle built for the U.S. Army Ordnance Tank-Automotive Command and shown in Fig. 9. This experimental vehicle represents the first attempt to extend the principle of articulated construction beyond two units and is powered by a single engine mounted in the front unit. All six tracks are powered at all times through a drive line with five differentials, two of which can be locked out by the driver. Steering is by two W.N.R.E. joints but normally only one joint, between the first and second unit, is used and the second trails freely. However, when the hydraulic pressure in the first joint system reaches about 800 lb per square inch, when the vehicle is executing tight turns for instance, the second joint is brought into play by pressure sensitive valves and helps the action of the first joint by turning in the opposite sense. This action might be clarified by considering the three units standing in line and the effect of operating the first joint only, which will tend to rotate each unit in place so that each joint turns in the opposite sense and the units form an "S": it is this motion which the second joint is designed to assist. The actual turning radius of the 42ft 8in long vehicle is about 30ft and in practice the steering system has proved satisfactory, with the successive units tracking the first closely even when snaking along narrow trails. Moreover, experience with the three-unit "Cobra" is said to have shown that the running gear can carry greater loads than in a two-unit vehicle because of lower working stresses.

The track assembly of the "Cobra" provides, in itself, a further point of interest as it embodies spaced-link tracks. These it inherited from the T60 amphibious carriers from which the three units of the "Cobra" were, in fact, modified. The T60 was a vehicle of the "Weasel" class designed to explore the use of spaced-link track which had been advocated by Bekker[20] and first demonstrated in the "Ground Hog" built

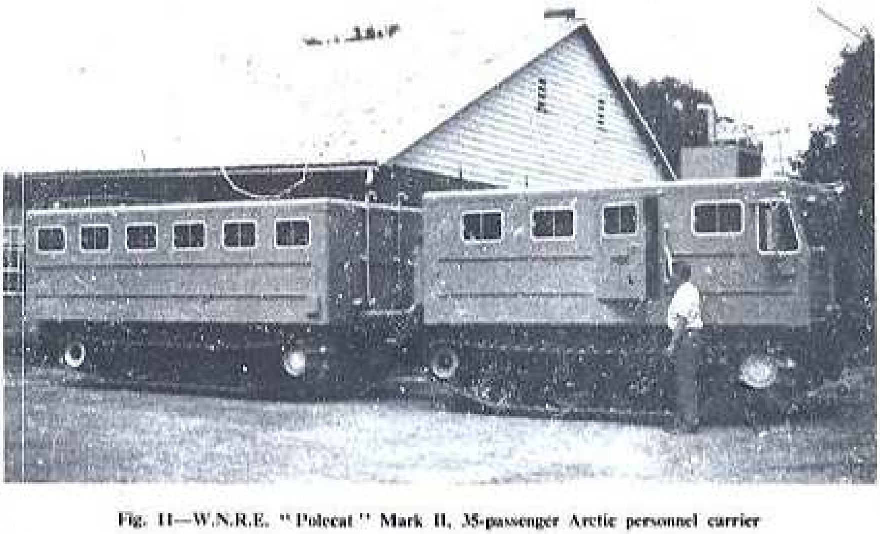

Fig. 11—W.N.R.E. "Polecat" Mark II, 35-passenger Arctic personnel carrier

during the late 'forties. It proved, as expected, superior to the "Weasel" in straight ahead motion in muddy terrain but the wide spaced-link tracks proved incompatible with skid-steering. This led to the conversion of the T60 experimental carriers into the units of the "Cobra" and the resulting combination of spaced-link tracks with articulated steering produced a practical vehicle of great promise for operation in difficult terrain.

The second of the three vehicles developed recently by W.N.R.E. is the "Polecat" Mark II. The prototype of this vehicle, shown in Fig. 10, has been running since October 1960 and has been renamed the "Terrapin" by the U.S. Army Transportation Research Command. It is a two-unit amphibious dynamometer vehicle with an overall length of 37ft 7in and a gross weight of 25,000 lb, which produces an average nominal ground pressure of 1·7 lb per square inch. A single 150 b.h.p. V-8 Chrysler engine located in the front unit drives all four tracks and with a five-speed synchromesh transmission the "Terrapin" is capable of a maximum road speed of about 35 m.p.h., while in water it can propel itself by means of its tracks at up to 3 m.p.h.

Two features of the "Terrapin" which call for particular attention are the method of articulation and the track assembly. The articulation joint is of the usual W.N.R.E. "Polecat" type with two 3½in bore 19in stroke hydraulic cylinders and allows up to 35 deg. of movement in either direction in the horizontal plane, which gives a turning radius of 38ft. However, in contrast to the earlier designs, there is also a third cylinder which provides damping in the vertical plane and makes the total length of the vehicle more effective from the point of view of ride over rough terrain. Ride is further improved by a new suspension with hydro-pneumatic springing and four road wheels on trailing arms on either side of each unit. In contrast to the original "Polecat," as well as the "Weasel" and the "Cobra," the "Terrapin" has special pneumatic tyres, which have been adopted increasingly frequently in place of solid rubber tyres for vehicles intended for operation on snow and marshy ground since the 1939–45 war and which have already been used on the M76 carrier, Nodwell's vehicles and the W.N.R.E. "Musk-Ox." The 35in wide tracks are also of the continuous band type now commonly used in soft ground vehicles and there are two 10in wide nylon and rayon reinforced rubber belts for each track with forged aluminium alloy track shoes swaged-bolted to the belts. The sprocket is unusual, however, in that it has nine rubber mounted roller teeth, a commendable design feature which reduces the possibility of sliding between mating surfaces and which recalls the roller sprockets of the half-track vehicles used extensively by the German Army during the 1939–45 war.

The "Terrapin" was built mainly for research work but the same chassis has been used since for the "Polecat" Mark II

Fig. 12—"Dinah" light general-purpose tracked vehicle designed for operation in difficult terrain

35-passenger arctic personnel carrier. This vehicle is shown in Fig. 11 and it has recently gone into service in Greenland, where it supplements the original and smaller "Polecats." It has a gross weight of 31,500 lb and is powered by a 194 b.h.p. turbo-charged Hercules diesel but in essence its design is similar to that of the "Terrapin," except that it is not amphibious.

The latest articulated vehicle produced by Wilson, Nuttall, Raimond Engineers is the "Dinah" shown in Fig. 12. This is a small general-purpose vehicle capable of carrying a total load of 1,200 lb, excluding the driver. It has a gross weight of 5,000 lb and is 17ft 4in long overall. The lower part of the hull of each unit is of welded low alloy steel construction but the upper part is of glass fibre reinforced plastic and the vehicle will float without additional buoyancy or preparation. All four tracks are driven by a single 42 b.h.p. two-cylinder Panhard engine located in the front unit, and the vehicle is capable of a maximum road speed of the order of 16 m.p.h. and can propel itself in water by means of its tracks at up to about 2 m.p.h., which is sufficient to cross still water. Higher water speeds may be obtained using an outboard motor for which a mounting bracket is provided.

As in the case of the "Terrapin," steering in water, as well as on land, is by articulation and the joint is of the now well-tried W.N.R.E. "Polecat" type. However, only one 2¼in bore 8in stroke cylinder is sufficient for control in the steering plane but there is a second cylinder of the same size in the pitching plane, which is normally locked for water operation and which acts as a heavy damper on land, improving the ride as in the case of the "Terrapin" and the "Polecat" Mark II carrier. The turning radius on land is 19ft 6in.

In other respects the "Dinah" also follows practice successfully adopted on earlier W.N.R.E. vehicles. Its tracks consist of nylon and rayon reinforced rubber belts with swaged-bolted steel shoes and are driven by sprockets with ten nylon rollers. The tracks are 20in wide and at full load give a nominal ground pressure of only 1·55 lb per square inch. Each of the two units has three road wheels per side independently sprung by means of trailing arms and Neidhart rubber springs, and having 8·00 × 6 pneumatic tyres.

Thus, the range of articulated tracked vehicles now extends from the 40-ton "Musk-Ox" down to the 2-ton "Dinah" and the even lighter 1-ton "Rat." Such a wide range of sizes provides ample evidence of the capabilities of this type of vehicle and in particular of its superior performance in snow and difficult marshy terrain. So far articulated tracked vehicles have been developed chiefly for operation under such particularly difficult conditions, where the need for them is greatest. But there is no reason why the application of this form of construction should not be extended to other fields, where it can offer the advantages of longer, narrower chassis, with all that this implies in terms of reduced resistance to motion and ground pressure, a better ride, and reduced soil stresses and power losses during steering. Application to armoured fighting vehicles presents difficulties because of the vulnerability of the joints and the hull shapes which go with them. In addition, articulated tracked vehicles can not make pivot turns and in general have larger turning radii than existing skid-steered vehicles. However, in several other fields the turning radius or silhouette of articulated tracked vehicles should not present any major problem and should be more than balanced by their other characteristics. This applies in particular to cross-country cargo carriers which are now receiving some belated attention.[21]

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## Technical Reports

*A Non-Destructive Method for Measuring the Elastic Anisotropy of Wood Using an Ultrasonic Pulse Technique.* By I. D. G. Lee, B.Sc. (Eng.), A.I.W.Sc. Timber Development Association, Ltd. (Research Report E/RR/9). Price 3s. 6d.—This report gives details of a method of testing alternative to static loading and slow vibration and, by the method outlined, it is possible to use the same specimen for all measurements in any one plane. Thus, extraneous variations resulting from irregularities of growth are greatly reduced. Elastic constants are determined by measuring the velocities at which three types of plane wave travel in known directions. The most convenient method was found in measuring the time taken for the onset of an ultrasonic pulse of longitudinal waves to travel across the diameters of a disc, each disc cut so that its circular face lay in the plane in which variations in the elastic modulus were to be measured. In the report, Mr. Lee effects a comparison between values of Young's modulus derived from wave velocities and theoretical values based on the assumption that wood possesses rhombic symmetry. Differences in velocity distribution in the end grain section (radial tangential plane) between hardwood and softwood species are discussed in relation to wood structure.

*A Comparison of Methods for Measuring the Mean Velocity of Rivers.* By Sheena G. M. Todd and J. Whitake. (Fluids Note No. 95.) Department of Scientific and Industrial Research National Engineering Laboratory, East Kilbride, Glasgow. No price quoted.—The discharge of rivers, when measured by velocity-area methods, is usually determined from a restricted number of point velocity measurements on each vertical, since complete velocity distribution traverses are often impractical because of changing stage. The accuracy of nine of these reduced-point methods is examined by comparing the results with the mean velocity obtained by planimetering fifty-six actual profiles plotted from three river gaugings in Holland, Italy and Russia.

The single point methods (at 0·6 depth and at 0·5 depth, times a factor 0·96 in the latter case) are shown to have mean standard deviations of over ±3½ per cent, with, in addition, significant permanent errors caused by systematic bias. The two and three point methods have mean standard deviations of about ±2 per cent, while the five and six point methods vary from about ±1 to ±2 per cent from the true mean velocity.

*An Improved Batching Counter.* By D. Nairn. D.S.I.R. National Engineering Laboratory.—A batching decade counter is described which enables commercial transistor decades to be used at their maximum counting frequency. It employs a simple diode network which recognises when a count of 998 is reached and causes the succeeding pulse to be gated to give out a batch pulse and generate a reset pulse. This action resets each decade of the counter to the nines complement of the required batch number. The main advantage of the counter arises from the fact that when the count changes to 998 only the least significant decade is involved so that all transient delays are settled within twenty-four microseconds (two microseconds delay in the first binary stage of the counter and twenty-two microseconds reset period). In normal methods used for batching there are unavoidable delays before it is known that a reset pulse is to be generated, and these limit the maximum frequency of the counter.

*A Fast Adding, or Subtracting, Transistorised Counter for Simultaneous Action from Two Random, or Periodic, Pulse Trains.* By W. H. P. Leslie and D. Nairn. D.S.I.R. National Engineering Laboratory.—This report describes a series of circuits, each constructed as a separate plug-in unit, which can be assembled to make straight or reversible counters. Their two main features are a high speed of count propagation through a binary or binary decimal counter, and an ability to deal with random pulses on each input line irrespective of the degree of overlap or separation of the pulses. The speed is such that an output pulse is available in two microseconds from commercial binary units having resolution times of ten microseconds, despite the fact that all twenty units in a five-decimal digit counter are being switched.

*Instrument Ball Bearings.* By P. J. Geary. British Scientific Instrument Research Association, South Hill, Chislehurst, Kent. Price 21s.—This is the fourth booklet of a series entitled "A Survey of Instrument Parts." During the past ten years the production of instrument ball bearings has greatly increased, while refinements in manufacturing techniques have made available bearings of greatly enhanced performance. The present publication offers a concise review of their characteristics and utilisation. Aspects of the subjects dealt with include tolerances, truth of running, avoidance of vibration and noise, frictional torque, lubrication, load capacity and life. The publication contains thirteen line diagrams and a bibliography of 144 references.