

THE SEGMENTED AIR TRACK AMPHIBIOUS ALL-PURPOSE ALL- TERRAIN VEHICLE

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Abstract

The state of the art of "All-Terrain Vehicles" is examined and found severely wanting. The concept of the Segmented Air Track is proposed as a possible true ATV. The configuration and structure of the SATC is explained and depicted in narrative and with listed advantages over the crawler tractor, the pneumatic tire, and the ACV. Four specific SATC vehicle designs are proposed and described, from a small four-passenger craft to a 50-ton payload tug for use in the Northern off-shore oil fields to move the new 300-ton ACV oil rig transporters all year round. A possible solution to the weak road load relief problem is proposed in the form of an SATC conversion of the semi tractor trailer truck tandem dual wheels to reduce ground pressure and increase flotation. Early calculations of air horsepower demand for four proposed SATC vehicles at various track pressures are provided.

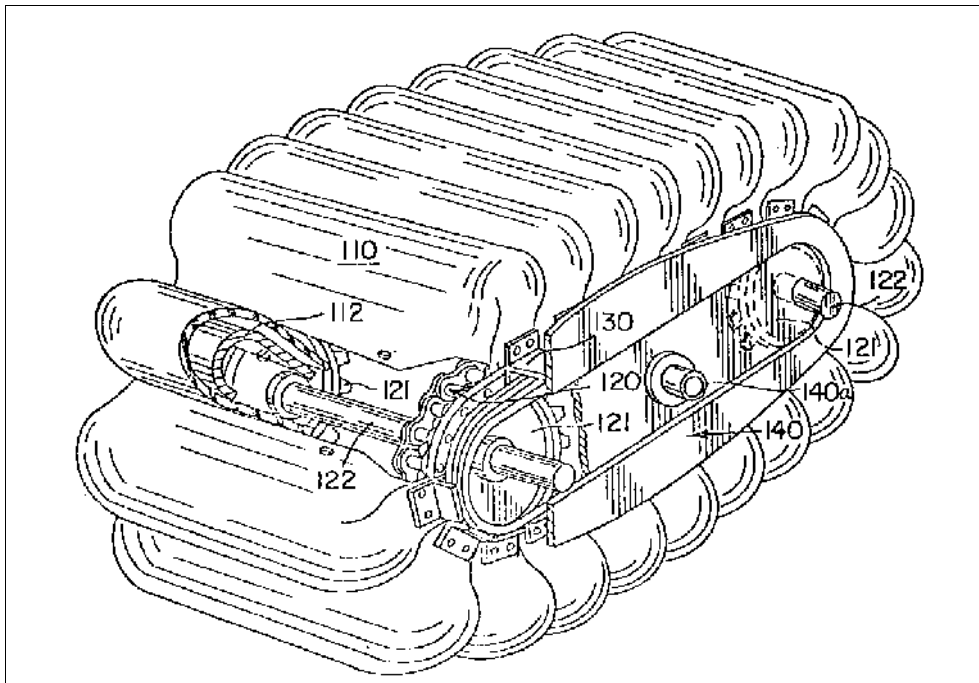


Fig. 1. Cutaway perspective view a typical dual roller chain, dual pair sprocket Segmented Air Track Unit

At this writing, there is no "All-Terrain Vehicle" which will negotiate all conditions of surface up to 45 degree grades on land and travel on water in all weather, all seasons, all climates the world around. The tracked vehicle, "Snowcat," tank, crawler tractor, etc., are excellent on mud, snow, or sand, but are lost on water, the Rover or dune buggy gets stuck in loose sand, mud, and are also lost on water. The Army Duck does well on solid surfaces and makes slow headway on water, but gets stuck in mud, the Rollegon vehicle does well on soft surface, but capsizes in slipping off solid land or ice into water (Ref. I); the ACV is fast on any level surface but cannot climb steep grades nor clear high obstacles and has inefficient low speed propulsion; the Archimedes screw vehicle performs adequately on water, ice floe, ice, but is destroyed on rocks, sand, etc. No combination of the above has produced a true "All Terrain Vehicle."

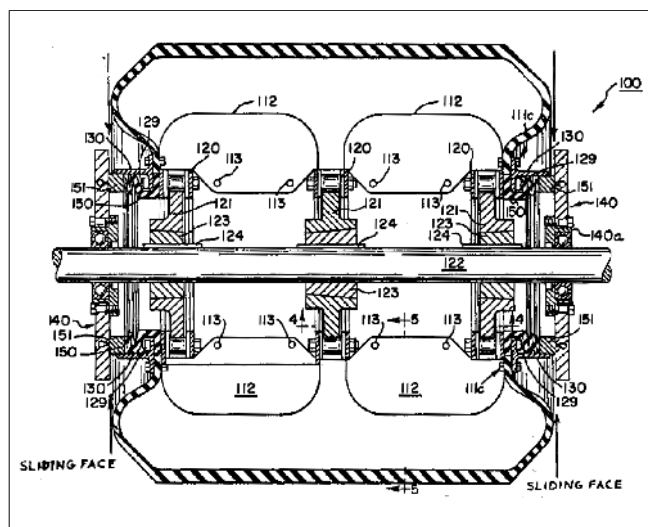


Fig. 2. Vertical cross section of a typical triple roller chain, triple pair sprocket Segmented Air Track Unit showing skid rests 112, slide plate 140 with air lubrication ports and sliding seal 151.

The Segmented Air Track Crawler (SATC) a concept as yet unrealized in hardware, is a proposed new modality of transport combining elements of the pneumatic tire, the crawler tractor, and the air cushion vehicle, possibly resulting in great versatility extending and enlarging the best features of each modality and obviating many of their limitations. It may become a true "All-Terrain Vehicle."

The basic SATC elements are shown in Fig. 1. It is an air cushion vehicle, the skirt segments of which are inwardly open and outwardly closed and are attached and sealed at each end to two roller chains running on four sprockets in orbital fashion like a crawler track. The roller chain also carries a seal which slides against a smooth plate attached to the main frame of the Air Track which mounts the sprocket shaft bearings. This sliding seal can be air lubricated through the slide plate perforations (see Fig. 2). This construction makes an air tight orbiting unit which can be variably pressurized by an external source to the desired degree and allows wide variation in the design height, length, and width of the crawler, unit since, in contrast to the crawler track, air pressure, rather than bogies or rollers, carries the load.

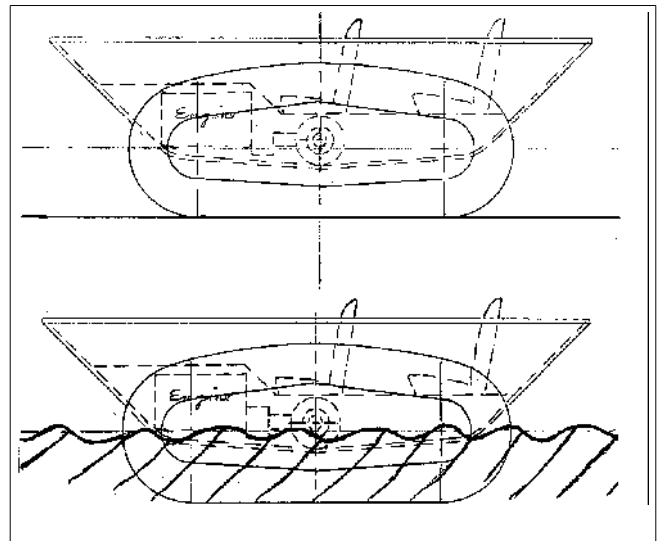


Fig 3. Phantom side views of Four Passenger Dual Air Track chassis only, without canopy, shown on land and in full amphibious operation in water in hydrostatic Air Track buoyancy.

The SATC promises to result in a vehicle less expensive than a conventional crawler and more expensive than a pneumatic tire or the simple ACV, but the probable capabilities of this tracked hybrid and its probable advantages listed below fully justify the cost and the research and development needed to produce it. Again, there is no other "All-Terrain Vehicle" in existence or in prospect. If the SATC lives up to its potential, it will be a product useful in all sizes for many tasks in every part of the globe.

I. Air Track advantages over the conventional girderized roller crawler:

1. Less active machinery, eliminating rollers and their bearings, suspensions, etc.
2. Less first cost and maintenance and operating cost.
3. Greater length and width possible than in roller crawlers.
4. Lighter in total weight with less mass to accelerate positively and negatively.
5. Less internal friction.
6. Capable of higher speed.
7. Variable tread pressures for different tasks or running full or empty.
8. Exclusion of dirt, debris, and water from the mechanism by filter air under pressure, lengthening machinery life.
9. Flotation in water with sufficient volume/weight ratio.

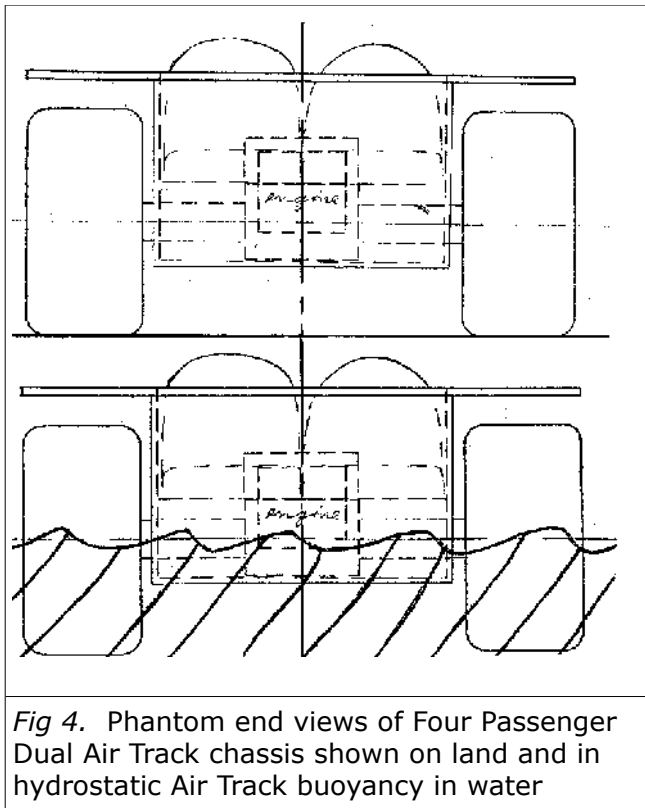


Fig 4. Phantom end views of Four Passenger Dual Air Track chassis shown on land and in hydrostatic Air Track buoyancy in water

II. Air Track advantages over pneumatic tires:

1. Lower silhouette for given ground contact area.
2. Single contact point vs. multiple points allowing less road flexion and self-cleaning

tread.

3. Greater ground contact area, allowing lower ground pressure.
4. Variable ground pressure for different conditions or loads.
5. Greater efficiency of larger Air Tracks because of diminished relative peripheral seal length.
6. No practical limit to size of Air Track, whereas tires are now at technical and economic limit of size.
7. Less internal friction and heat generation.
8. Cheaper first cost, less material used per sq. ft. of traction area.
9. Field repairable without casing removal compressors, jacks, cranes, etc.
10. Self-damping bounce, inherent shock absorption.
11. Puncture proof.
12. Higher salvage rate for slashed casing. A pneumatic tire would be scrapped; a segmented Air Track can have one or more segments replaced in the field.

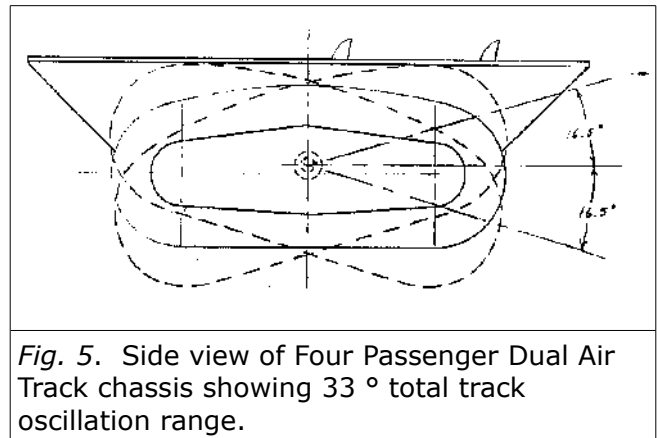


Fig. 5. Side view of Four Passenger Dual Air Track chassis showing 33 ° total track oscillation range.

III. Probable advantages of SATC over ACV's

1. Powerful, positive propulsion, steering, braking and control with inherent yaw stability.
2. Steep grade climbing, hill holding, and side hill negotiation.
3. Greater pressures can be economically maintained with the smooth sliding seal and raceway as compared to open bottom ACV skirt with greater air gap dragging over uneven terrain.
4. No great efflux of base air emitted at ground level to stir dust, spray, and debris.

5. More compact units can be designed to make vehicles of massive load carrying capacity "roadable" at very low base pressure.
6. No erosion of the surface, no permeation of the substrate by cushion pressure, and no "sandblasting" of nearby objects occurs since the very small and economical seal efflux occurs well above ground level.
7. The SATC has inherent water flotation in the pressurized compartmented unit.
8. Effective, efficient propulsion and steering on water is inherent because of the great "paddle wheel" area of all moving base of the Air Track unit.
9. In contrast to the ACV, the skirt of which is dragged across rough, abrasive surfaces, there will be little relative motion of the Air Track segments against the ground except tractive effort slippage.
10. Much higher obstacle clearance will be possible with the SATC than with the ACV.
11. Greater economy of lift air power demand is probable even at higher base pressures because of the excellent prepared seal and race vs. the ACV skirt over uneven, varied, rough terrain. Air lubricated seals should reduce friction and wear to near zero.
12. Greater economy of propulsion power is almost certain with positive ground traction vs. the air propelled ACV at relatively low speed and therefore low air thrust efficiency.

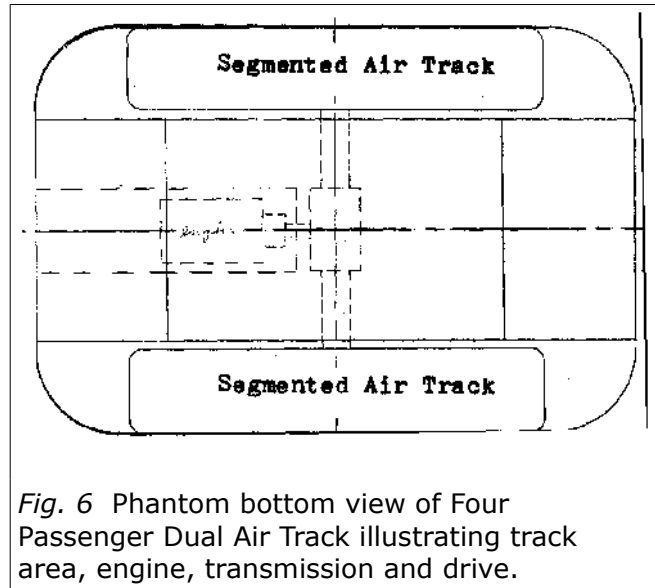


Fig. 6 Phantom bottom view of Four Passenger Dual Air Track illustrating track area, engine, transmission and drive.

USES AND APPLICATIONS OF SATC TECHNOLOGY

When developmental objectives such as sliding seal efficiency, durability, and reliability have been achieved, the applications of segmented Air Track technology are truly vast in types of vehicle, tasks, topographic, meteorologic, and geographic utility.

Proposed SATC Vehicle No.1

A "Model T" four-passenger truly "All-Terrain" craft is a very real possibility (Figs. 3,4,5,6,7, 8,9 and Table I). Such a rugged utility craft, unlike its nearest rivals, the Cushman Trackster, the four, six, and eight wheel Rollegon vehicles, would be buoyant with full propulsion, steering, and land speed. Water speed of two MPH is the usual velocity for these extant craft. It is my belief that the Segmented Air Track will achieve "hump speed" and climb out of its static buoyancy immersion depth to travel on the surface above 5-10 MPH, depending on the length of the craft. The descending leading edge of the Air Track segments will climb on the inertia of the bow water; its delay in moving away from the rapidly downwardly cascading segmented belt will force the nose of the craft upward. As the process of applying segment after segment faster than the water can yield continues, the entire craft will be lifted to and maintained on the surface as long as the track velocity is sustained. The improved

efficiency and increased top speed per propulsive horsepower, if hump speed is achieved, is obvious. A corroborating analogy to this "hump speed" theory is the observed phenomenon of the non-buoyant snowmobile and its ability to skitter across a narrow open water area at high speed without observable sinking. All too many snowmobiles, however, have tragic outcomes on thin ice.

The proposed SATC has 100% gross weight buoyancy in each of its two widely spaced tracks which are designed to be only 50% or less immersed in full gross weight' operation. The wide stance, nearly eight-foot beam, plus the great buoyancy of each track unit, should render the craft quite stable and capsizing-resistant in sliding off sideways, for instance, from an ice shelf, or a sheer drop shore edge with the water level near or below the solid surface.

Proposed SATC Vehicle No.2

An Articulated Tandem Dual Segmented Air Track Vehicle for carrying either moderate loads amphibiously, or massive loads on land with very low base pressures of 10 psi or less (Fig. 8, Table II). This roadable vehicle of eight foot maximum width has two articulated units with segmented Air Track belts seven ft. by seven ft. length and width, covering most of the entire bottom of the craft. As shown in Table II, the total base area carrying the load is 98 sq. ft. or 14,112 sq. in. At one psi base pressure the craft will carry 7.056 tons and float in water 27" deep. At 2 psi it carries 14.112 tons and floats 54" deep. At only 3 psi pressing on the ground this craft carries 21.168 tons and in water will be immersed 71". Beyond a gross weight of 21.168 tons or 3 psi, it is, of course, not longer amphibious but continues to carry more and more weight as the base pressure is raised. This small craft carries 70.56 tons of weight at the very low base pressure of 10 psi to bear on the ground, highway, Sand, mud, snow, etc. It is a true All-Terrain Vehicle.

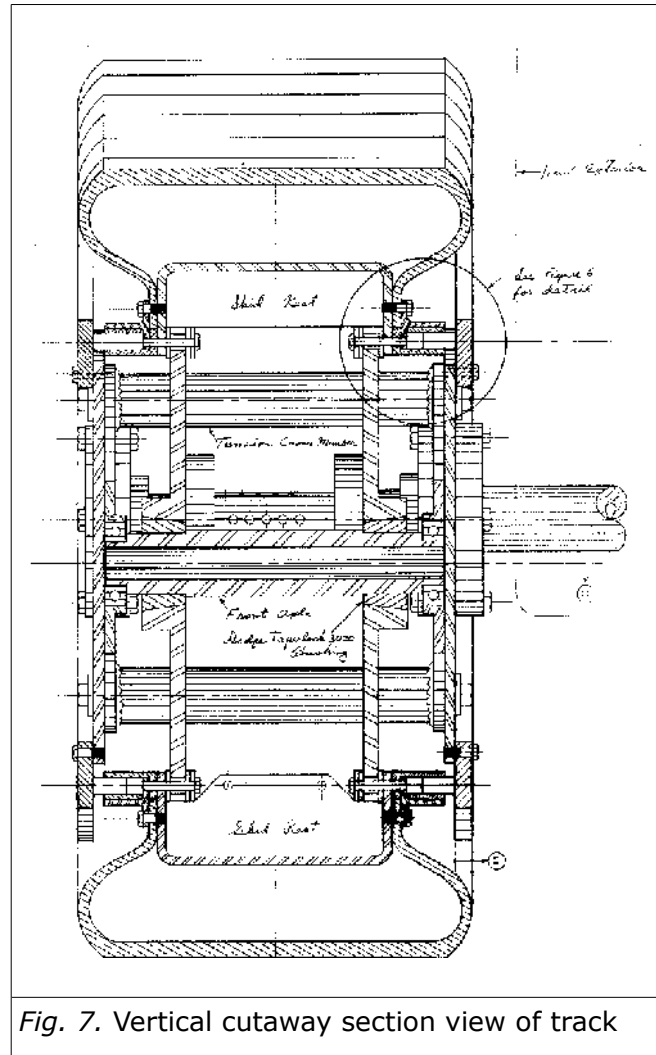


Fig. 7. Vertical cutaway section view of track

Proposed SATC Vehicle No. 3

To illustrate the possibilities for growth of the SATC craft and to offer the offshore oil drillers in the Beaufort Sea in efficient tug for pushing or pulling their 300-ton ACV oil rig transporter, now under construction, on land and sea the year round (Ref. I), we have proposed a 50-ton payload, 100-ton gross weight vehicle shown in Fig. 9; specifications are in Table III showing four 15 foot square area SATC units on each corner of the craft, each one of which would support 50% of the gross weight when fully immersed and any two of which would support 100% of the gross weight fully immersed, making the craft more stable than barges or conventional ACV's. The total movement of the immersed buoyant parts should provide tremendous paddle wheel propulsion and

drawbar pull. On land the traction should be even greater. This too, huge as it is, is a true All-Terrain Vehicle. And this is not the maximum size nor load carrying capacity of the SATC concept. Theoretically, millions of pounds of SATC capacity can be built for amphibious operation.

Proposed SATC Vehicle No.4

In 1977 (Ref. 2) David Eyre, Senior Research Scientist of the Saskatchewan Research Council, made a plea to air cushion designers to provide lift during the Spring banned period when heavy loads are forbidden on the public roads due to their weakened state during the Spring. To quote Ref. 2, " ... there is one compelling argument in favor of such development [air cushion assist for prairies weak road load relief]--the number of potential users is one or two orders of magnitude greater than the total number of potential users of all other vehicle types." In other words, the market for such a device is huge, probably the largest of all ACV markets.

In the 1970'S the National Research Council of Canada did extensive studies on air cushion lift assist of semi trailers and other techniques for load relief (Ref. 3). None was considered feasible with "conventional" ACV or extra wheels, Rollegons, etc. Four billion tons of commodities, ore, overlay, and other cargo cross Canadian prairies annually, most of it in semi tractor-trailers, and it slows drastically during the three months of each year as the Spring break-up occurs. This is a period when maximum equipment and materials movement should occur and is, therefore, a severe, continuing, unresolved economic deprivation.

In 1979 the author made two presentations (Refs. 4 and 5) which proposed the conversion of semi tractor-trailer tandem dual wheel sets to enclose them in a belt with peripheral seals, side pressure plates, and external air pressure supply to pressurize the unit to increase the

ground contact area from 3 sq. ft. to 30 sq. ft. per tandem dual set to allow reduction of ground pressure to 10 psi or less instead of 75-100 psi.

Continued design work on the Air Track concept has produced significant improvement in the crawler unit itself, such as the segmented track vs. the early belt design and the mounting of the track on roller chains for positive torque transmission, better track retention, and increased tensile strength. The substitution of inflated segments like ACV skirt "fingers" will allow greater "squash" and better acceptance of surface roughness. The sliding seal was moved radially inward from the periphery to the chain root center line, no longer subject to surface roughness, shorter in length, and stabilized by the rigidity of the roller chain (Figs. 1 and 2). Fig. 1 is an approximation of the appearance of SATC Vehicle No. 4 tandem dual wheel set conversion to Segmented Air Track, and Fig. 2 is a vertical transverse section drawing of a similar unit. Fig. 10 is a horizontal section drawing of the tandem dual set with the wheels removed and three sprockets substituted on the wheel mount studs to carry three roller chains on which both the track segments and sliding seal are mounted. Side pressure plates carry the stationary seal race against which the sliding seal presses, and it may be air lubricated through ports shown in Fig. 2 to reduce friction and wear, increasing durability. The existing dual wheel suspension, axle torque drive, and braking, of the tractor and trailer remain intact and effective.

If feasible, this SATC adaptation and retrofit to existing tractor-trailer units will eliminate the persistent, unresolved prairie weak road relief problem. It would also allow off-road operation of these rigs and overload condition on-road the rest of the year. To reiterate, this could be the greatest of all ACV markets.

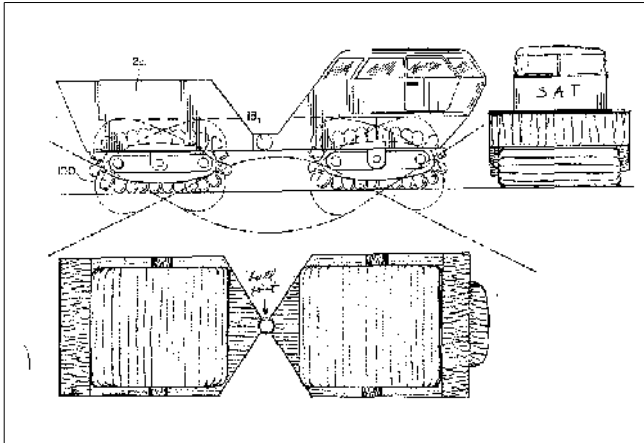


Fig 8. Three view drawing of Articulated Tandem Dual Segmented Air Track Vehicle with near total base area Air Track

CONCLUSION

We have only begun to experiment with orbiting SATC seals and can logically expect improved seal efficiency and less leakage through innovation of seal techniques. As ACV operators, we are accustomed to vast air volume flows at low pressure escaping from the base of our vehicle skirts when on cushion, and dedicate about one-third of the installed horsepower expenditure to lift air. In the Air Track with our early, first generation seals, we can expect a constant seal gap and therefore a graduating air supply demand increase with increasing track pressures and increasing Air Track vehicle size. The Air Track alone, in contrast to the ACV, allows base pressure to rise above one or two psi maximum.

Table IV shows calculated raw horsepower demands of each of the four proposed SATC vehicles described herein at track pressures ranging from one to 10 psi assuming a seal gap of 0.001 inch. This air gap is only an assumption and presumes no improvement over a mere smooth race with low friction seal materials sliding over it. Air lubrication is not considered, nor is any estimate of seal friction included with or without air lubrication. It is very early in Air Track art. The SATC is at about the same stage as the ACV was before the advent of the Bliss segmented finger skirt which produced at least an order of magnitude increase in lift efficiency.

The Segmented Air Track concept in any of its variations is hereby proposed for further R&D and field testing to determine the full range of its application and utility.

TABLE I Specifications of "Model T" Four Passenger Segmented Air Track All-Terrain Vehicle:

Gross weight: 3,000 Ibs.,
Empty weight: 2,000 lbs.,
Payload: 1,000 lbs.
Flotation (fully amphibious): in tracks @50% immersion, 4,800 lbs., in Hull, 3,000 Ibs
Track dimensions: overall length, 90", overall height, 42", width, 18".
Power: 50 HP gasoline engine.
Speed: on land, 20 MPH+, on water, 10 MPH+.
Grade climbing: 45 degrees.
Obstacle clearance: 16".
Tread pressure: on ground @3,000 lbs. gross wt: 1.4 psi (area of tread contact 60" x 18" x 2 tracks = 2,160 sq. in).

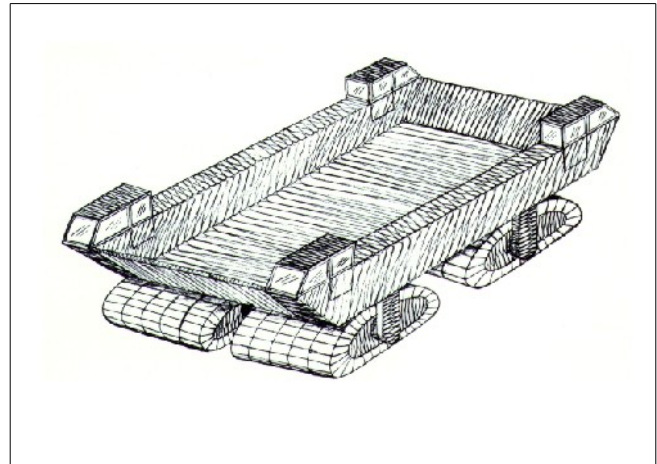


Fig 9. 50 Ton Payload Air Track Tug

TABLE II Capacities of Articulated Tandem Dual Segmented Air Track Vehicle (two 7'x7' crawler tracks carrying the vehicle, total 98 sq. ft. (14,112 sq. in.) weight bearing area:

PSI	Carrying Capacity	Flotation Depth
1	14,112 lbs. (7 tons)	27"
2	28,224 lbs. (14.1 tons)	54"
3	42,336 lbs. (21.2 tons)	71"
4	141,120 lbs. (70.6 tons)	--

TABLE III 50 Ton Air Track Tug Specifications.

Overall Dimensions: Height on solid surface on cushion, 21 ft., height on solid surface off cushion, kneeling, to well deck, 8 ft., overall, 17 ft., Width, 38 ft, Length, 56 ft.,

Well Deck and Cargo Bay dimensions: Depth, 6 ft., Width, 32 ft., Length, 45 ft.,

Gross weight:, 210,600 lbs. (105.3 tons).

Flotation: Fixed permanent in structure, 220,000 lbs. (110 tons and 4.7 tons greater than gross weight)

Maximum Air Track Buoyancy: at 100% immersion, 421,200 lbs. (210. tons or twice the vehicle gross weight).

Normal Air Track Buoyancy: at 50% of track height immersion (25 of track length immersion), 210,600 lbs. (105.3 tons, equal to craft gross weight).

Maximum Payload: of full gross' weight, 114,600 lbs. (57.3 tons).

Power: Four 1,000 HP Diesel engines.

Tread Pressure on ground: 2 psi.

Speed: On water, two to 20 knots; on land, maximum 30 kts.

Grade climbing: 45 degrees or whatever slopes traction will allow.

Drawbar Pull (estimated): On water, 80,000 lbs. On land, 160,000 lbs.

Maximum Obstacle Clearance: 8 ft.

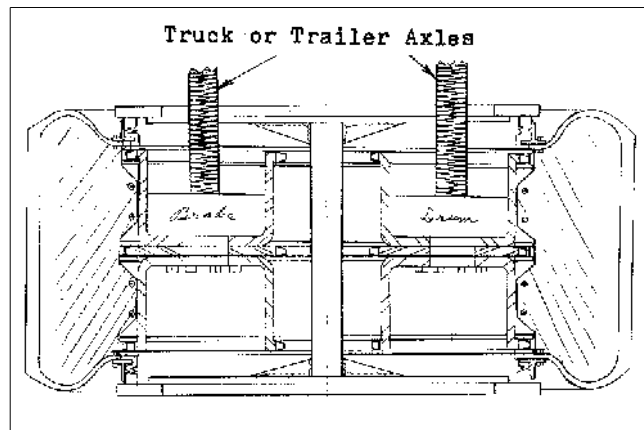


Fig. 10. Horizontal section of Tandem Dual Semi Tractor-Trailer wheel set conversion to Segmented Air Track Crawler

TABLE IV		"Model T" Four Passenger SATC #1	Articulated Tandem Dual SATC #2 Whole Bottom Area Tracks	50-Ton Payload Air Track Tug SATC #3	Semi Tractor- Trailer Tandem Dual Wheel Conversion to SATC #4
Total Seal Length		720"	720"	2,880"	800"
Total Seal Orifice A ⁰		0.001"	0.001"	0.001"	0.001"
$\frac{\text{PSI (Po/Pa)}}{\text{in AirTrackChamber}}$	A ⁰ Speed of Sound in Air Track Chamber ft./sec.	Seal Air Horse- power Required	Seal Air Horse- power Required	Seal Air Horse- power Required	Seal Air Horse- power Required
1	1128	0.89 HP	0.89 HP	3.57 HP	0.99 HP
2	1137	1.87 HP	1.87 HP	7.47 HP	2.08 HP
3	1147	2.93 HP	2.93 HP	11.73 HP	3.26 HP
4	1157	4.08 HP	4.08 HP	16.33 HP	4.54 HP
5	1165	5.31 HP	5.31 HP	21.24 HP	5.90 HP
6	1172	6.60 HP	6.60 HP	26.43 HP	7.34 HP
7	1181	8.00 HP	8.00 HP	32.00 HP	8.89 HP
8	1188	9.45 HP	9.45 HP	37.81 HP	10.50 HP
9	1195	10.98 HP	10.98 HP	43.92 HP	12.20 HP
10	1202	12.58 HP	12.58 HP	50.33 HP	13.98 HP

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