Tests on an air-cushion assisted trailer ACAT-1: test stage 6: completion of road, gravel road & soft track tests 15 ton total load (including lift system)

Fowler, H. S.; Rueter, F.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40003881
Laboratory Technical Report (National Research Council Canada. Division of Mechanical Engineering. Engine Laboratory); no. LTR-ENG-43, 1975-07

DIVISION OF MECHANICAL ENGINEERING

DIVISION DE GÉNIE MÉCANIQUE

CANADA

PAGES / PAGES 17

FIG. / DIAG.

REPORT / RAPPORT

SECTION

REPORT / RAPPORT LTR-ENG-43

DATE / DATE July, 1975

LAB. ORDER / COMM. LAB. 19737A

FILE / DOSSIER 6040-2-8

LIMITED

FOR / POUR

REFERENCE / RÉFÉRENCE Discussion with Dr. D.C. MacPhail

LTR- ENG-43

Tests on An Air-Cushion Assisted

Trailer ACAT-1.

Test Stage 6.

Completion of Road, Gravel Road & Soft Track Tests

15 Ton Total Load (Including Lift System).

SUBMITTED BY / PRÉSENTÉ PAR Dr. E.P. Cockshutt
SECTION HEAD / CHEF DE SECTION

AUTHOR / AUTEUR H.S. Fowler ~~F. Rueter~~

APPROVED / APPROUVÉ Dr. D.C. MacPhail
DIRECTOR / DIRECTEUR

CONTENTS

1. SUMMARY

The ACAT-1 vehicle has been driven over a variety of "road" surfaces, (hard concrete, gravel, soft woodland track, and sand.) Its performance over these has been assessed, and effective skirt wear has been monitored quantitatively by measurement of lift airflow and road relief.

The program was finally halted when skirt-wear reduced the maximum attainable load relief to 20%, as results were no longer valid.

The data are presented, and the whole test program is discussed. Conclusions are given, and recommendations are put forward for consideration.

2. HARD ROAD TESTS

2.1 As reported in LTR-ENG 42, Stage 5 testing concluded with the first 7½ miles of driving of the vehicle. This is briefly summarized as follows:

A. A static test showed 100% load relief to be easily obtainable (i.e., with some engine RPM in hand).

B. A total of : -2 miles at low lift RPM at 5 mph,
3 miles at 50% load relief at 5 mph,
⅓ mile at 50% load relief at 10 mph,
⅓ mile at 50% load relief at 15 mph,
⅓ mile at 50% load relief at 20 mph,

5¾ miles approx. (all on concrete road).

At the end of this, subsequent tests showed that 100% load relief was just obtainable, at max. RPM. Inspection of the skirts showed serious wear, in a definite pattern, repeated by all jupes. This is reported in detail in LTR-ENG-42.

9th June

Draft report on Test Stage 5 was discussed with Mr. D. Jones, Mr. E. Kimber, and Mr. C. Harcourt of Hoverjak. It was agreed that the blow -off valves were not functioning, and upsetting the system performance by forcing the jupes down into the knuckled-under position. Unusual wear was therefore caused. In view of the limited time available, it was agreed to continue running in an effort to wear down the skirts to an appropriate level at which they would be expected to attain the designer's intended "tip-toe" configuration, with a small hovergap.

It was agreed that all future runs should be at 80% load relief, as corresponding to the 250 lb/in. wheel loading maximum legal figure on the trailer wheels. The tractor wheels would be slightly less heavily loaded.

2.2 Stage 6

Stage 6 commenced with tests (Runs 3, 4 and 5) at the weighing platform, to check the rear suspension calibration, and to get sets of readings at 100% and 80% load relief.

A main flexible air duct from the blower exit box burst, but adequate repairs were made. The end connections of these ducts appear to be a weak point in need of revision.

The vehicle was driven off the scale platform, the 6" step of which was negotiated up and down without difficulty a number of times, and thence 2700 ft. to the concrete test oval, on concrete road, at 80% lift, at 10 mph.

The 10,000 ft. oval concrete road was driven round at 10 mph, and again at 20 mph. This track is slightly banked on the 600 ft. radius circular ends, and presented no difficulty in control.

In the three demonstration circuits of the oval track at 10 mph and 20 mph (two laps) the Hoverjak group were well pleased with the performance, and thought that little further skirt wear would take place.

The DND driver used the brakes cautiously and accelerated vigorously at 80% load relief. He commented that the vehicle showed no unpleasant characteristics, and used far less power to pull than a corresponding orthodox vehicle.

No readings were taken, but it was noted that lift RPM had to be increased to the maximum permitted, at full throttle, to maintain the desired 80% lift. This deterioration of performance appeared to progress rapidly during the latter (20 mph) laps.

The vehicle was then driven back to the parking space, a further 2700', at 10 mph., giving a total of 6 miles on concrete during the day.

2.3 10th June

Dr. R. Young (McGill University) inspected the vehicle, which was then run at 20 mph from the parking place to the oval track, and for one lap round the track. It was noted that the front lift pack runs a little nose-up, and the rear pack a little nose-down (probably less than 1°) as seen from a track alongside. Both packs did follow the road contour quite perceptibly, pitching and heaving slightly, at 20 mph, with an estimated ± 1" movement.

At the start of this run, having set the system to 80% load relief at the start (25.5 psi on rear suspension bag gauge) a complete set of readings was taken (Run 6-1). It was then noted that at 2930 RPM engine (full throttle), it was only possible to generate (31 psi) approximately 60% load relief, - possibly owing to greater airflow under the skirt. The jupes had worn substantially to designed condition (particularly on the trailing 120° arc) with a vertical edge ("tip-toe") and a distinct hovergap of up to ½ ", instead of the previous knuckled-under condition. The abraded edges presented a surprisingly clean-cut appearance.

After this, the vehicle was set up at max. obtainable load relief (approx. 60%), and the continuous recorder switched on, (Run 6-2). The vehicle was then driven at 10 mph across 500 ft. of concrete road, onto a gravel road, and for 2/3 mile along this, to the concrete road, and back to the parking place. The gravel road included an unbanked 400 ft. radius 200° turn. The dust raised was formidable, although the surface was not "dead dry dusty" by any means. Movies of the vehicle and a truck at 20 mph a few minutes later show this dust. The dust-skirts had been hauled up out of action, but subsequent tests show that they are not very effective.

This day accounted for 3½ miles of running, of which 2¾ miles was over concrete at up to 20 mph, and 3/4 mile over gravel road at 10 mph.

3. SOFT TRACK TESTS

It was decided in view of the rapid skirt wear that soft track tests should be run next, with gravel road tests as the final phase. Mr. Myles and Mr. Richenhaller (Dept. of Environment) assisted in a reconnaissance, and it was decided that a route through the S.E. corner of the LETE site (Course 42 & 39) would give sandy area, hard dry lane, and soft woodland track conditions. Mr. Richenhaller and Mr. Woods made soil tests in the soft woodland track. (See Appendix 1).

On 19th June, the vehicle was driven with retracted skirts to the entrance to the sandy area, and the skirts lowered. The lift system was set up to full power and RPM and moved off into the sandy area at about 10 mph. Continuous recordings were taken at intervals throughout this trial. The first area traversed was of hard, slightly damp sand, and was covered at 10 mph with no difficulty raising practically no dust. (600 feet)

The vehicle then moved along about 700 feet of hard sandy earth lane, with a 3"/6" humps in the middle between wheel tracks. This was traversed easily at 10 mph without any appreciable dust or disturbance to vegetation at the sides. A sharp 90° turn was then made without difficulty into a soft track through dense woodland. The track was disused, and very weedy, but no difficulty was experienced for the first 300 feet. At this point the tractor (normal tyres) lost traction and came to a halt. The wheels had sunk 6" deep ruts in the soft and slimy soil, raising a hump between them, which was probably scrubbing the tractor differential casing, and certainly dragging heavily on the lift-pack skirts and box. The vehicle was unable to move further under its own power, but despite the uneven rutted ground, lift did not appear to be lost.

The DND observers had anticipated this state of affairs, and moved in a recovery vehicle, which was unable to tow the ACAT directly, but took up position ahead and winched the ACAT forward by cable, in 200 ft. steps.

During this procedure the lift system was kept at full power and the tractor was still endeavouring to become self-propulsive. The towline behaviour made it clear that not much additional effort was required, and indeed mud-tyres on the tractor might have enabled the ACAT to traverse the track unaided.

The vehicle was finally brought out onto the gravel perimeter road and drove a further 2100 feet on this unaided. The skirt was then retracted and the vehicle driven back to the parking area.

A total of about 1 skirt-assisted mile over soft track and some gravel road, at 10 mph or less, partly driven and partly towed, was made good during this trial, and no appreciable skirt wear was detected.

4. GRAVEL ROAD

There was no doubt as to the ability of the vehicle to drive over this road, which had a hard flat surface, but the expected wear was a matter of debate, and the figure '8' course with unbanked 400 ft. radius 200° curves at each end gave an opportunity to assess quantitatively the road-holding ability on curves. The dusty nature of the road also gave a comparison of wheeled and air cushion assisted vehicles as dust raisers, and a measure of the effectiveness of the dust-skirts fitted to ACAT-1.

The tests had to be conducted in the most economic manner possible, as it was realised that the remaining skirt life was short. On 23 June the vehicle was driven to the figure '8' track, and driven round it twice to get the feel of the vehicle in its unassisted state. The DND test driver suggested that 30/35 mph was the maximum safe speed, with the concrete load on board, on these curves. The writer drove a Volvo car with radial tires round at the same time, and found signs of drift at 40 mph.

Films of a truck, and ACAT on these runs show the moderately heavy dust raised by a normal vehicle.

The skirt of the ACAT was lowered into operating position, with the dust skirt still rolled up, and the lift system set to max. rpm and power. Only 68% load relief was attained. The vehicle was then driven round the figure '8' a distance of 1.1 miles, at 15 mph, with the continuous recording operating. Film shot from the roadside showed an extraordinarily heavy dust cloud raised, hiding the rear half of the vehicle. The dust raised was extremely fine, and hung in the air up to 50 ft. high until a faint breeze drifted it clear, minutes later.

This run was repeated immediately, with the dust skirt lowered. No appreciable reduction in the dust was seen, and while hovering over a hard surface it was seen that the lower edge of the dust skirt was being blown up off the ground by the air escaping from the jupes. On this run, only 52% load relief could be attained at full throttle.

The next run was made at 20 mph, with similar results, but only 36% load relief was possible at full throttle.

A further run at 25 mph produced similar characteristics, with approximately 40% load relief. A final run at 30 mph approached the driver's estimated safe speed limit, and showed only 20% load relief at full throttle, reduced RPM, and very high airflow from the lift system.

At first sight, one might have said that the ACAT showed no deterioration in road-holding ability from normal wheeled version of the same vehicle, but when it was realised that this was with only 20% of the load relieved it was clear that skirt-wear had invalidated the arguement, and that no conclusions on road-holding could be deduced from these tests.

On the other hand, both these and the Hard Road tests show the excessive wear rates over any type of road, and suggest that wear increases badly with speed.

The total skirt mileage over the gravel track in these tests was approximately 5 .

Finally, the vehicle was driven at 30 mph, down a straight concrete road, and the trailer brakes applied vigorously. Faint rubber streaks indicated a straight smooth stop, but the driver's subjective comment was that the braking effect was much less than usual. With only 20% load relief, the result is not particularly useful.

At this point tests were discontinued, owing to skirt deterioration.

TABLE 1. Summary of Total mileage & Skirt Wear

Test Point	Total Miles	Road	Speed	Load Relief	Lift Airflow*	Lift RPM
A	0	Static	Static	100%	231 ft^3. /sec	3255[xx]
B	1			63	83	2130
C	1½			63	140	2130
D	2	Rough Concrete	5/10 mph.	57	100	2130
E	3½			63	170	2500
F	4			59	190	2500
G	6			50	70	1860
5-2	6	Static	0	100	270	3210[xx]
5-4	6	Static	0	82	160	2565
6-1	15½	Concrete	10/20	60	300	2934[xx]
8-1	16½	Sand/Soft	2/10	40/80%	280/320	2965[xx]
9-1	17.6		15	48/64ϕ	272/280	2965[xx]
9-2	18.7		15	52/64ϕ	267/275	2910[xx]
9-3	19.8	Gravel Road	20	36/64ϕ	268/272	2855[xx]
9-4	20.9		25	40/54ϕ	269/272	2785[xx]
9-5	22.0		30	20/44ϕ	270/275	2767[xx]

* Corrected to standard day conditions
xx Full throttle, max. lift obtainable
ϕ Static Relief/Relief while moving.

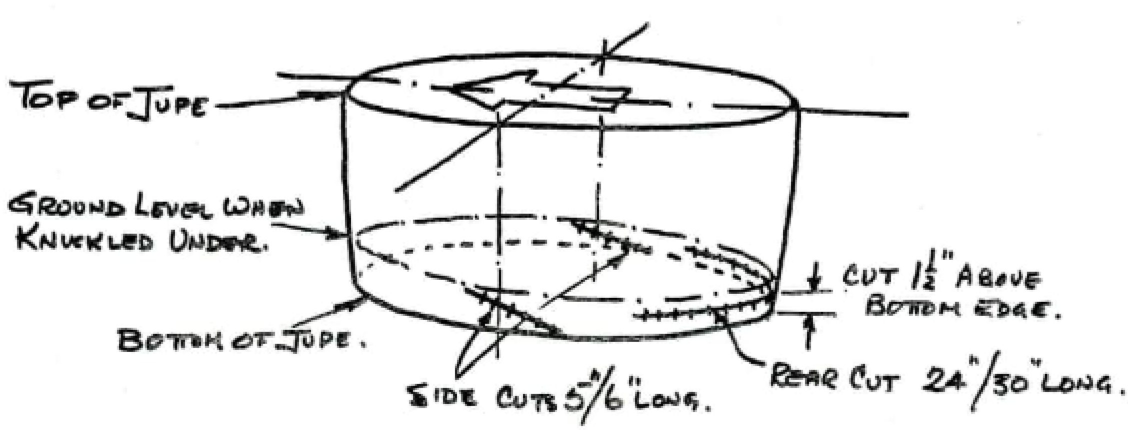
6. DISCUSSION OF SKIRT WEAR

The question of skirt wear was discussed in some detail in LTR-ENG-42, based on the first 7½ miles of operation, at 50% load relief. A further 15 miles has been travelled, at reliefs of from 100% down to 20% with a badly worn skirt, at speeds of up to 30 mph, over concrete road, gravel road, sand, and soft ground. There has been no alteration to the pattern of the wear damage on each jupe, so the earlier discussion is quoted here for ease of reference:-

"DISCUSSION OF SKIRT-WEAR (from LTR-ENG-42)

(a) Observations

To date it appears that skirt wear is due mainly to about 7½ miles of operation over poor concrete road at 50% load relief (of a 15 ton load). It is noted that the blow-off valves in the lift pack bags have not been operating and that the airboxes are leaking, probably with a greater total flow than the blow-off valves would provide. There is also an intermittent very large leak (usually leaking) between the aft lift pack rear centre curtain (partial jupe) and the aft right jupe. Under these conditions, every jupe is knuckled-under to an extent of about 2½" (witnessed by scrape marks on jupes, see photo 1A3, Fig. 8 for example), and the knuckled-part folds in a pattern closely repeated from one jupe to another, over all the jupes. The material then scrapes on the ground with great force along the crests of the folds, causing abrasion, and finally cutting clear through the material in a precise and repeatable pattern.



ONE JUPE, SHOWING PATTERN OF CUTS.

(b) Discussion

This vehicle is unlike the normal free-flying ACV, in that in the present case the skirt is not free to adopt its own hoverheight, but is vertically constrained. The vehicle frame is held a specified height above ground by the wheel suspension, and the lift pack airbag, plenum box, skirt (jupe), plus any hoverheight (positive/gap or negative/knuckle-under) have to divide this height between them.

The only exception to this is when local bumps or dips in the ground between the vehicle wheels temporarily alter this available total height from frame to ground. These alterations are intended to be accepted by expansion or contraction of the lift pack airbag, while the jupes remain fully extended ("on tip-toe") with a constant small positive hovergap. This expansion or contraction is intended to be substantially a constant pressure process, controlled by a bag feed orifice and a blow-off valve.

The above is our understanding of the design philosophy of the Hoverjak System.

In practice, the blow-off valves are of such absurdly poor mechanical design that they are not operating, and at the operating condition noted the jupe is knuckled-under about 2½", while the lift pack airbag is stable at almost full extension. In effect, the failure of these valves to operate is completely crippling the performance of the lift packs." [End of quotation]

It was noted at the beginning of the present test sequence (Stage 6) during the 100% relief run on June 9th, that the skirt box did not rise appreciably [less than 1" rise] when the relief was increased from 50% to 100%, so that the degree of knuckle-under did not change from the earlier tests.

From this point on, the wear pattern did not rise further up the jupes, but simply became more severe in the existing pattern and place. The rear 120° cut parallel to the jupe lower edge became more definite, and the partly detached ribbon of material ripped off. The "tails" from the two side cuts became more damaged, and in most cases ripped off. The remaining lower edges of the jupes had the rubber eroded off on the downward facing side (usually the outside) leaving bare scraped nylon.

Effectively this formed a jupe in the designed "tip-toe" configuration, with a rather ragged lower edge. This configuration is clearly a far less effective seal than the original knuckled-under arrangement, and the airflow increased accordingly. The increased airflow required greater power input to the blower, and when this reached the engine operating limit and passed it, the inevitable result was a loss of rpm and a reduction in the cushion pressure and available lift.

The final jupe condition was recorded in detail photographically.

APPENDIX 1.

Actual weights of vehicle, lift system, and load, and actual lift performance.

In LTR-ENG-35, estimated weights of the vehicle and lift system are given.

In LTR-ENG-41, measured weights of the complete vehicle, including lift system, instrumentation and cabin observer, and concrete load blocks, are given.

The final phase of the test was to strip the vehicle and weigh the items of the lift system, instrumentation etc.., which had been considered as part of the socalled "payload".

The results were as follows: -

Instrumentation (Incl. Observer)	790 lbs.
Observer's cab, railings, etc..	620 "
Engine/Blower Assy.	4170 "
Blower airbox	500 "
FWD Lift Pack	1890 "
Aft. Lift Pack	1890 "
Concrete blocks & Hold-down bolts	21300 "
Total Load on Trailer	31160 lbs.

In LTR-ENG-35 (p. 4 & 5) estimated vehicle and lift unit weights are quoted from the original PAIT spec., as:

Weight of Trailer =	14000 lbs.
Payload (Incl. Lift Pack)=	40000 "
Gross weight =	76000 "
(therefore Tractor =	22000 "

Max. weight on cushion (90% of payload)=35700 lbs. (i.e. Case IIa).

By actual weighing (LTR-ENG-41)

Tractor & Driver=	16200 lbs.
Trailer only=	23300 "
(with lift pack & insts., but without concrete)	
Concrete Load	21300 "
Therefore Total Gross	60800 "

Max. lift obtained was 100% of 21300 lbs. (Table 1, test A & 5-2) which is only about 67% of the actual load on the trailer (31160 labs), and only 60% of the designed lift (35700 lbs, =90% of designed payload).

Extra 4000 lb concrete blocks had been cast for the trials but were not used as it was seen that the lift available was not sufficient for them.

It must be noted that from other tests on similar engines there is a strong suspicion that the engine develops only about 150HP at the permitted 3200 RPM, instead of the 200HP assumed in the design. It should also be noted that no overheating was experienced during the trials.

APPENDIX 2. SOIL CONDITIONS ON SOFT TRACK

Secondary Road Hauling - using A.C.V. assist trailer.

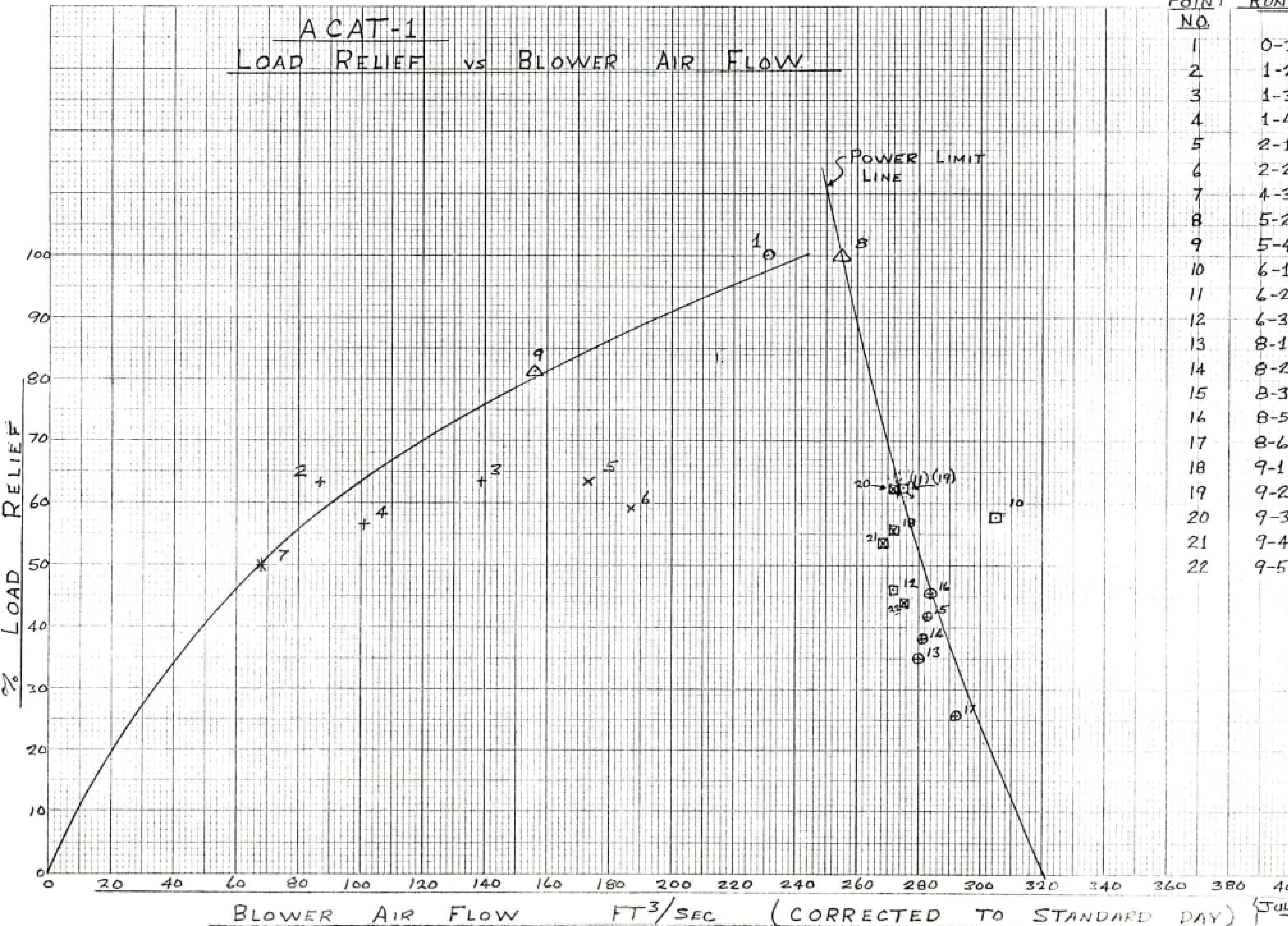
The following soil samples were taken after a recent heavy rain in the area and in the middle of an existing old vehicle track portion of the trail, of a typical bush truck haul road. A four-wheel drive vehicle went over the route and indicated a sound bottom to the road, although a wet area was included to give the selected route the necessary characteristics of a typical bush truck secondary hauling road.

On the first portion of the road the tires of the ACV assist truck trailer formed a rut of 4 to 6 inches in depth. However, the crown or the area between the tracks created another problem by adding an additional 6 inches, thus limiting the clearance.

Soil samples were taken with a cone penetrometer giving readings of pressure and shear. Since this instrument gives readings which have to be translated to meaningful values by feeding the data into a computer, it is therefore not available at this time. However, the readings taken at the locations were very similar. The cone used was the smaller of the two supplied with the instrument.There was only a partial penetration of the cone ranging from 2 to 3½ inches which indicated a solid base. However, at both test locations the shear readings indicated rather slippery surface conditions.

The surface soil consisted of clay load with a sand base forming the main road bed.

J. Richenhaller
Dept. of the Environment
Forest Management Institute.



POINT NO.	RUN NO.
1	0-1
2	1-2
3	1-3
4	1-4
5	2-1
6	2-2
7	4-3
8	5-2
9	5-4
10	6-1
11	6-2
12	6-3
13	8-1
14	8-2
15	8-3
16	8-5
17	8-6
18	9-1
19	9-2
20	9-3
21	9-4
22	9-5

APPENDIX 3.

PAGE 15.

JULY 3/

A C A T - 1

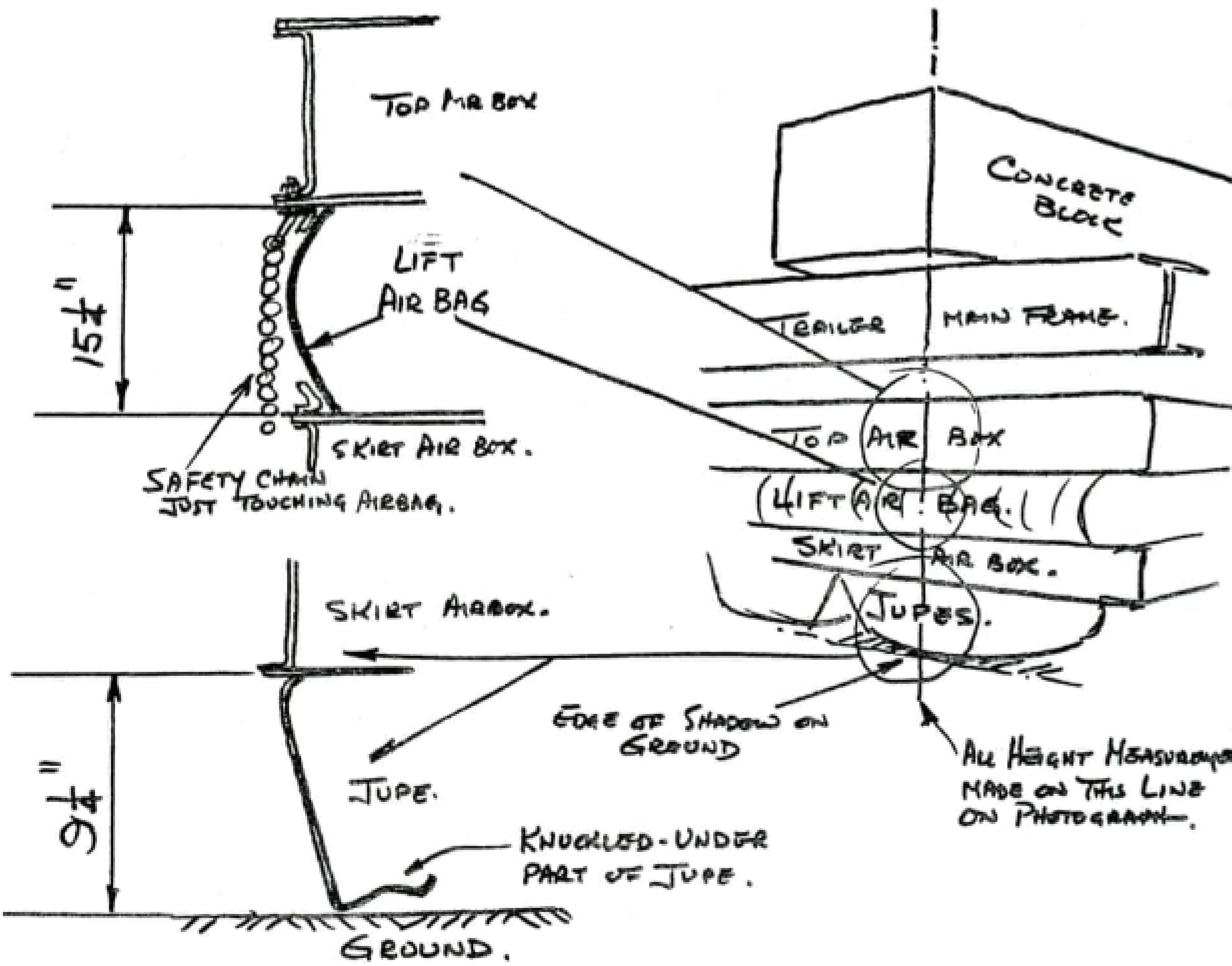
Run Summary

Graph Identification no.	Run no.	Air flow (ft^3/sec)	% Load Relief	Remarks (M= Moseley recorder) (Galvo= Pen recorder)
1	0-1	230.6	100.0	Max. obtainable lift (M)
2	1-2	87.3	63.5	Trailer static (M)
3	1-3	139.0	63.5	Trailer moving at 5 mph; Blower was adjusted while moving (M)
4	1-4	101.3	56.5	Trailer static (M)
5	2-1	173.5	63.5	Trailer static (M)
6	2-2	186.7	59.2	Trailer moving at 5 mph. (M)
7	4-3	68.2	50.0	Trailer static (M)
8	5-2	255	100.0	Trailer static max. obtainable lift. (M)
9	5-4	156.0	81.5	Trailer static (M)
10	6-1	305.4	57.8	Trailer static max. obtainable lift (M)
11	6-2	274.9	62.5	Average (Galvo)
12	6-3	271.5	46.0	Average (Galvo)
13	8-1	280.0	35.0	Max. obtainable lift. (Galvo) Trailer moving sandy Rd., (Avg.)
14	8-2	281.0	38.0	(Avg) moving sandy Rd. & grass (Galvo)
15	8-3	282.6	41.8	(Avg) moving forest Rd. (Galvo)
16	8-5	284.1	45.6	moving, (Avg.) being towed (Galvo)
17	8-6	292.4	25.7	(Avg.) moving dirt Rd. (Galvo)
18	9-1	272.0	55.7	(Avg.) moving Gravel Rd. (15) mph (Galvo)
19	9-2	275.3	63.6	(Avg.) moving @ 15mph.Gravel Rd. (Galvo)
20	9-3	272.0	63.6	(Avg.) moving 20 mph. Gravel Rd. (Galvo)
21	9-4	268.7	53.7	(Avg.) moving @ 25 mph. Gravel Rd. (Galvo)
22	9-5	275.3	44.0	(Avg.) moving @ 30 mph. Gravel Rd. (Galvo)

APPENDIX 4.

MEASUREMENT OF EXTENSION OF AIRBAG AND SKIRT

A photograph of the vehicle hovering over a flat gravel road at the end of the soft-road test was analysed to determine the extension of the lift-pack airbag and the jupes, at 80% load relief. Observations showed that these extensions were almost constant over a range of load relief.



Measurements made at the middle of the Left hand side of the rear lift-pack. Front lift-pack was at exactly the same height, as the photo clearly showed.