



LOOK BEHIND YOU!

A guide to trailed equipment braking



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Acknowledgements

This document has been prepared through the Service Managers Group of the Agricultural Engineers Association (AEA) and represents a common understanding relating to the use of trailers and trailed implements with tractors.

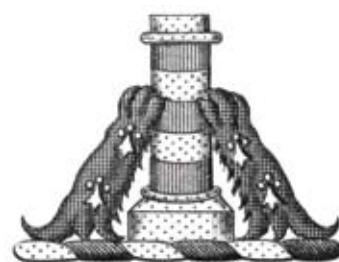
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The British Agricultural and Garden
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Introduction

With the current trend for higher road speeds of 40-50 km/h in the UK and Ireland with the use of “eco transmissions”, it is imperative that we have the correctly matched trailed equipment for the intended speed and loadings seen in daily use.

Currently, we have an industry- wide problem of “under braked” trailed equipment being used. This in turn can lead to premature tractor brake wear or even failure, causing customer dissatisfaction and conflict over who covers the repair costs.

In this guide, we aim to highlight the relevant legislation and to guide you through some of the available specs/ speed ratings of trailed equipment.

This will help to build a pro-active approach to investigating trailed equipment and aid the prevention of tractor brake failure.

With this information you will be able to guide your customer in the purchase of the correct specification of tractor or trailed equipment for their speed and application.



The effect of speed and vehicle weight

When travelling, a tractor and trailer combination builds up kinetic energy. To slow down or stop, the kinetic energy must be converted to heat through friction in the tractor and trailed equipment braking systems. Both systems are designed to withstand and dissipate the heat generated at their rated operating weights and top road speeds.

Travelling faster or operating at greater weights increases the kinetic energy levels the braking systems have to cope with, but there's a sting in the tail in the form of forward speed.

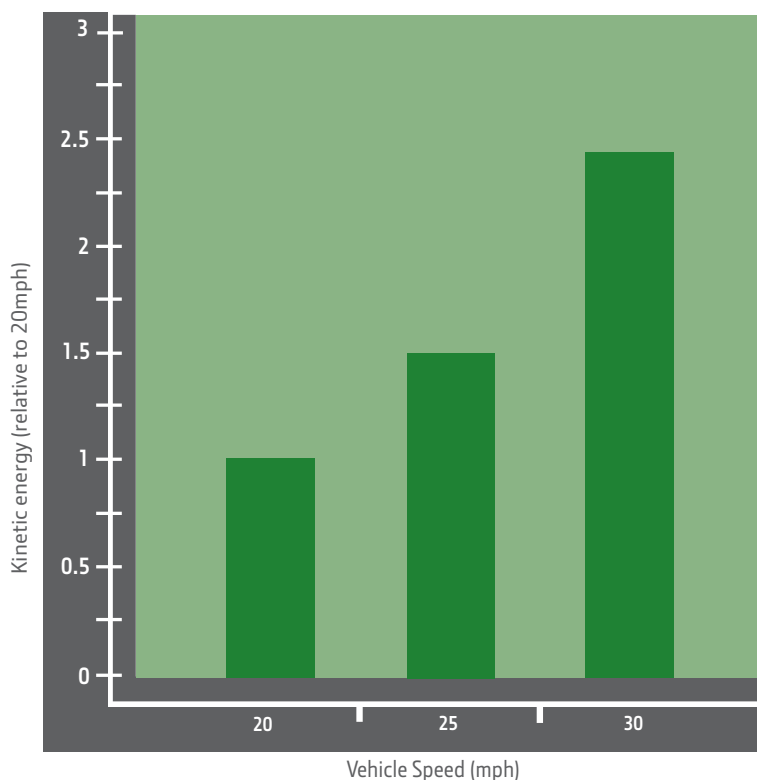
Forward speed

If, for example, the total (gross) weight of a tractor/trailer combination were increased by 50%, at any given speed its kinetic energy and the resulting braking system load would also increase by 50%. But if speed were increased by 50% (e.g. from 20 to 30 mph), kinetic energy would increase by almost 150% (see chart opposite).

What may be thought to be an everyday speed increase actually places nearly 2½ times more load on the tractor and trailer's braking systems.

This is fine if the braking systems are designed to take these speed induced loads, but those fitted to many agricultural trailers are not. In these instances, braking while

“over speeding” will subject the tractor and trailer braking system to heat cycles outside its design specification and cause accelerated wear. If not adjusted frequently, the responsibility for braking is progressively transferred to the tractor. This then causes rapid wear of the tractor's system and eventual long term damage to braking components.



Current (Legal GTW) tractor trailer combinations generate nearly 150% more energy when travelling at 50Kph.



Current UK agricultural vehicle braking legislation

Prior to the introduction of harmonised European braking regulations for agricultural trailers & trailed equipment, UK legal requirements are specified by the Road Vehicles (Construction and Use) Regulations (1986) and subsequent relevant amendments. Irish regulations mirror those employed in the UK.

The C&U Regulations effectively split agricultural trailers and trailed equipment braking requirements into two speed related categories.

Up to 20 mph/32 km/h:

C&U Regulation 16 applies.

- Trailer service brake must generate at least 25% braking efficiency when fully-laden.
- Service braking system must act on at least half the wheels/axles.
- Single-line hydraulic or pneumatic brake actuation is acceptable, but if trailer gross weight exceeds 14,230 kg, the service brakes must be operated directly from the tractor's service braking system.
- Parking brake must act on at least half the wheels & stop them from rotating when applied!

Above 20 mph/32 km/h:

C&U Regulation 15 applies as for commercial vehicles.

- Trailer service braking efficiency must be 45% minimum.
- Service braking system must be dual-line and failsafe, but not necessarily pneumatic. The driver must be able to apply the trailer brakes should any part of the towing vehicle's braking system fail. The trailer brakes should also apply (automatically) if the tractor-trailer accidentally separates.
- ABS (antilock braking) has been required since 2002.
- Parking brake must hold the laden, uncoupled trailer stationary on a 16% slope.

So, if travelling faster than 20 mph, UK law requires nearly twice as much trailer braking performance plus additional safety features to deal with the unexpected. In either case there is a legal requirement to adjust and maintain braking systems in good and efficient working order.

Coincidentally, the higher speed requirements (except ABS) are very similar to those proposed for future EU-wide introduction.



Construction & Use Regulations also specify maximum operating weights for both trailers and tractor/trailer combinations

Conventional 'unbalanced' agricultural trailer:

- Max. weight = 18,290 kg

Tractor/trailer combination:

- Max train weight = 24,390 kg

In practice, current UK regulations prohibit the use of trailers exceeding approximately 14 tonnes carrying capacity.

So what is braking efficiency?

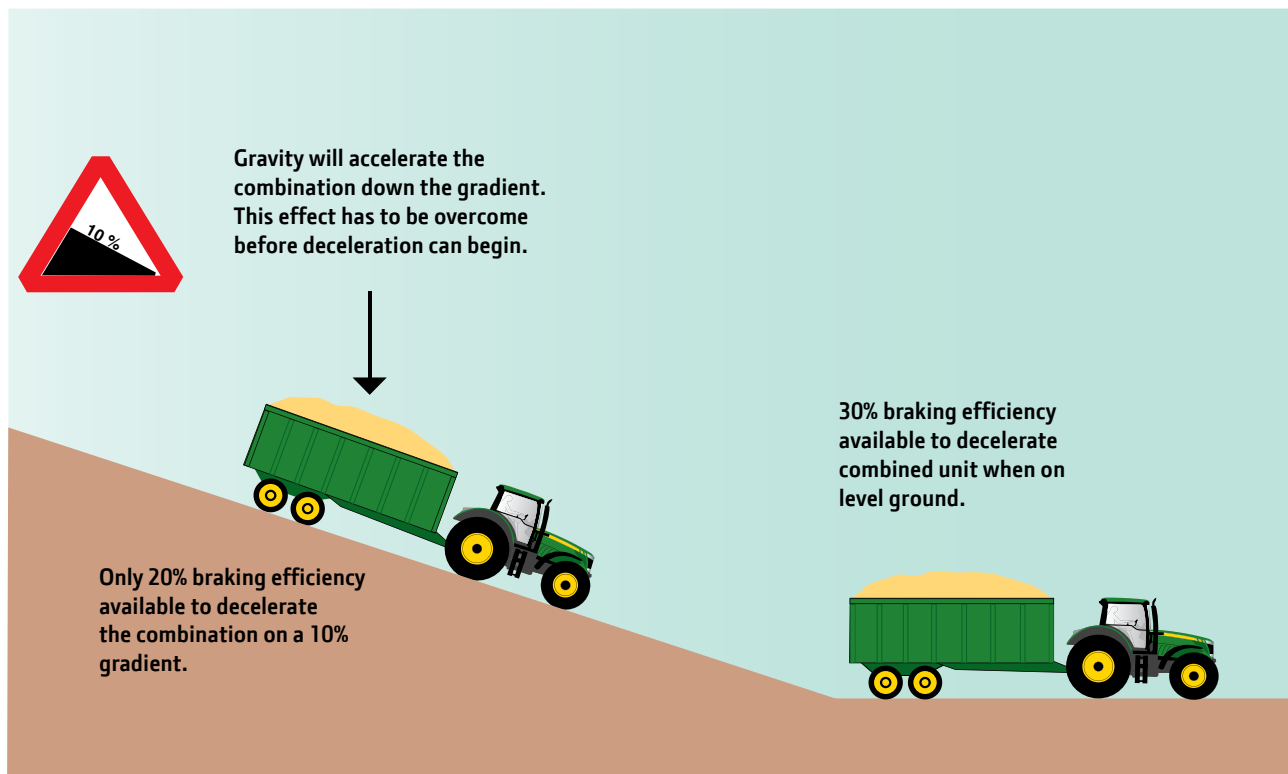
Braking efficiency is the overall measure of vehicle braking performance (the terms braking rate or brake ratio are also sometimes used).

$$\text{Braking efficiency (\%)} = \frac{\text{Braking force exerted by the wheels}}{\text{Vehicle weight}} \times 100$$

So, a 14 tonne capacity twin axle trailer, loaded evenly to have a gross weight of 18.29 tonnes, would typically carry 8 tonnes on each axle. To achieve 25% brake efficiency will therefore require each axle to produce 2 tonnes of braking force.

This would increase to 4 tonnes braking force to meet the approx. 50% braking efficiency requirement for above 20 mph operation.

Effect of gradient upon vehicle braking performance



A tractor/trailer with a combined braking efficiency of 30% can apply all that braking effort into stopping on level ground, but when travelling down a gradient it must overcome the weight acting down the gradient first. So, on a 1 in 10 gradient (10 %) this leaves only 20% for stopping.

A vehicle travelling down a gradient requires more braking effort to stop than a vehicle travelling at the same speed on level ground. This is because on a gradient, gravity will try to accelerate the vehicle downwards; the brakes have to overcome this effect before they can begin to stop the vehicle.

The best way to consider the effect of gradients is to think in terms of percentage gradient. A 1 in 10

gradient is a 10 % slope. In this way the fraction of a vehicle's weight acting down the gradient is equal to the percentage slope of the gradient.

So, to ensure that a vehicle can travel safely down a gradient, the total braking efficiency must be equal to, or greater than the gradient expressed as a percentage, plus the amount of braking efficiency necessary to stop the vehicle.



Trailed equipment specifications

With the trend for 40 and 50 km/h tractor speeds increasing, it is imperative that the trailed equipment braking system is matched to the speed and load requirements of the user and routinely maintained, if tractor brake failure is to be avoided.

What is the 'Foundation Brake'?

All other things being equal, trailer braking performance depends upon brake size and the force with which they are applied. The brake drum and shoes form the 'foundation' of the braking system. They are referred to in terms of drum diameter and shoe width. Higher capacity axles and/or those used at higher speeds tend to be fitted with larger foundation brakes. Making the wrong choice for your intended use could prove to be a costly mistake.

What is an 'Ag. spec axle'?

These are generally 6 or 8-stud hubs with a typical brake drum diameter and shoe width of approx. Ø300x60 mm or 10-stud hubs with Ø400x80 mm foundation brakes. These axles are usually intended to produce 25% braking efficiency (This spec can be used at up to 20 mph/ 32 km/h). Ag. spec brakes also use 'flat'-type operating cams which tend not to provide very progressive brake control.

What is a 'High-Speed/ Commercial Axle'?

Caution required here!! There is a general opinion that any trailer with 10-stud hubs and super single wheels and tyres is high-speed spec. This is not necessarily the case, as this wheel equipment is often used on Ag. spec 20 mph (32km/h) max. trailers.

A true "high-speed" spec axle will usually have Ø406x120 mm or Ø420x180 mm foundation brakes operated by 'S'-type cams to give progressive control.

The sheer size of the drum indicates how these brakes are able to dissipate the heat produced during higher-speed braking. Depending on the air chamber or brake ram size fitted, these axles/brakes will achieve 50% braking efficiency when fully-laden.

If fitted with dual-line failsafe and ABS systems, trailers featuring these axles can be towed above 20 mph (32km/h), although UK C&U Regulations prohibit such speeds if used behind conventional (unsuspended) agricultural tractors).

So, you've selected decent-sized axles and foundation brakes for the operating loads and maximum road speeds your equipment will work at. Problem solved? Not necessarily!

Unless the brake actuator (hydraulic ram or air chamber) produces sufficient force, overall braking performance will be compromised. (See graph on page 12).



Ø400 x 80mm Ag. spec: Bonded shoe
'flat' cam actuation



Ø420 x 180mm high-speed brake:
Riveted shoe 'S' cam actuation



Ø25mm actuating ram: Ag. spec



Ø35mm actuating ram - Commercial spec

Actuator specifications

Actuator specification

Trailer brake actuating rams and air chambers come in a range of diameters; bigger rams produce more force. Brake actuators push the brake lever arms/slack adjusters to operate the brakes and can be attached in different holes to achieve various degrees of leverage.

Trailer manufacturers match the brake actuator size, lever arm length and foundation brake size to suit the intended operating speed and load capability of the trailer. Operate heavier or faster and the braking system will be both inadequate and overloaded.

Brake ram diameter typically goes up in 5 mm steps; moving up a ram size will increase brake application force (but not necessarily overall braking efficiency) by 30-50%.

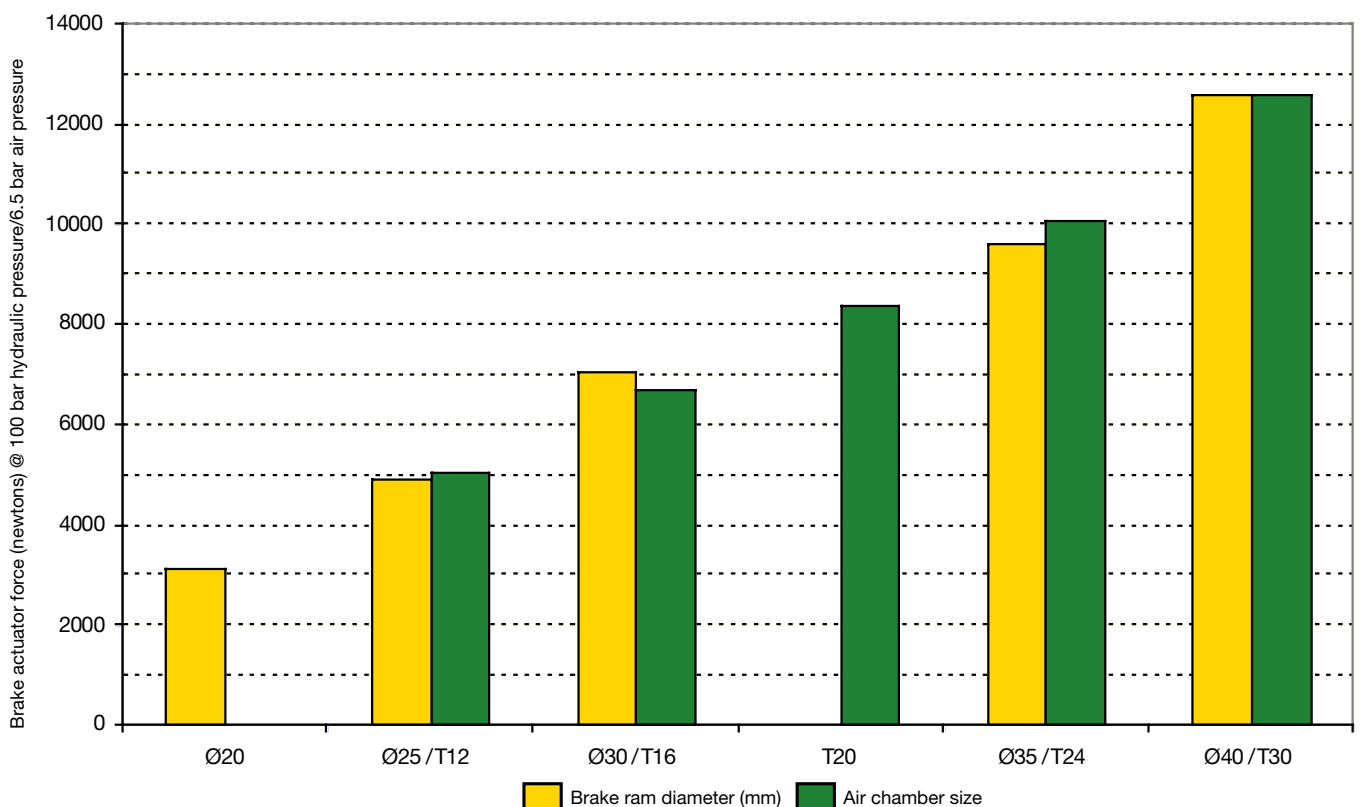
Most air-braked trailers intended for higher-speed (50% braking efficiency) operation are fitted with Type 24 air chambers.

A hydraulic braking system would need Ø35 mm rams to achieve comparable performance, so don't be surprised if the Ø25 mm hydraulic rams fitted to dual-supply (air + hydraulic) actuators don't

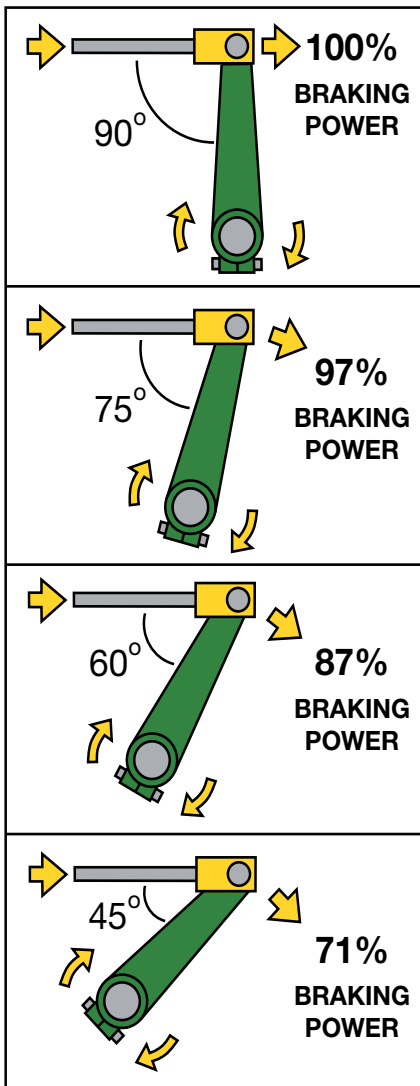
seem to deliver the same braking performance as the pneumatic system.

Where both air and oil are fitted to a trailer, manufacturers frequently size the hydraulic system to deliver 25% braking efficiency (for use up to 20 mph (32 km/h), specifying the pneumatic system to provide 50% efficiency for use above 20 mph (32 km/h).

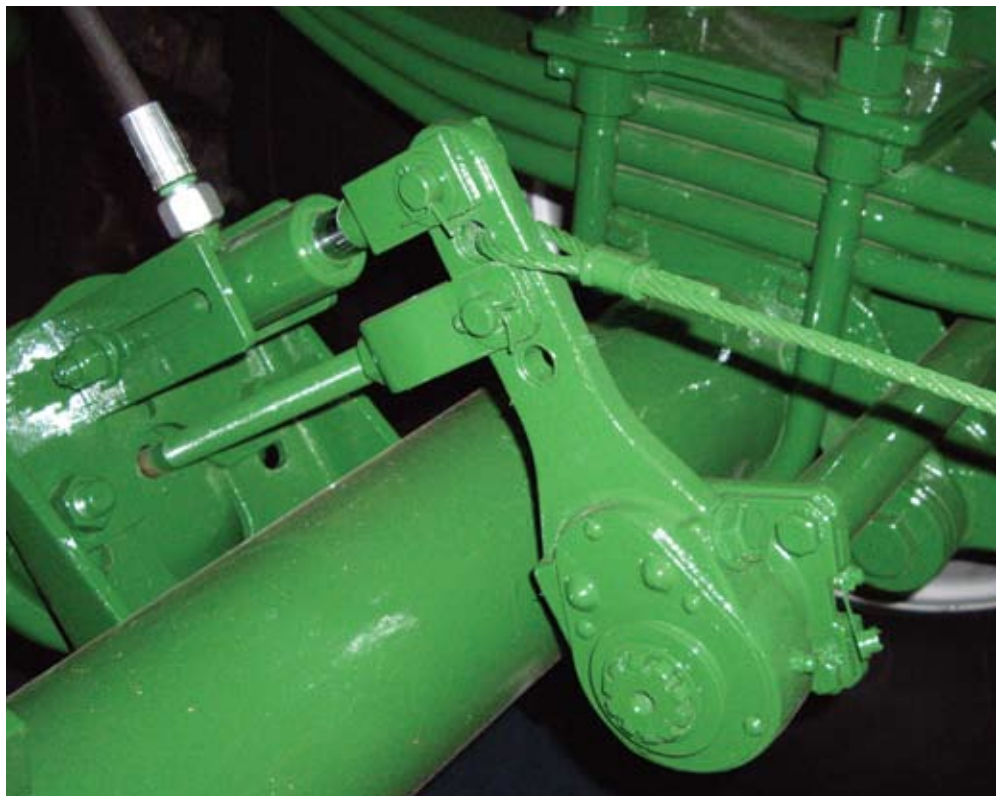
Unless both systems are fitted with load sensing, the chances are that the hydraulic system is only rated for lower-speed use.



The effect of brake actuator diameter/size upon on actuation force

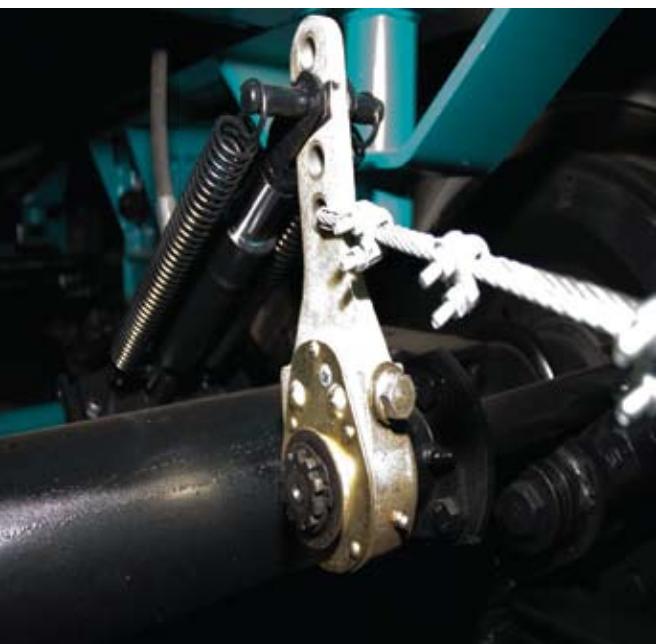


The effect of brake actuator/lever arm angle upon efficiency of force transfer



90° angle (Brakes on) giving 100% braking force

Regular actuator adjustment is important for two reasons: firstly, the reaction speed of the foundation brake is directly affected by the distance the actuator and lever arm has to travel. Secondly, the angle between the actuator and the lever arm has a direct effect upon brake shoe application force and the overall braking effort produced. Maximum force is applied when the angle is 90 degrees.



Screw type brake lever arm aids easy adjustment



Splined brake lever arm: free-play adjustment requires removal from camshaft and replacement on alternative spline

Too much braking?

If the foundation brakes and actuators are large enough, 50% trailer braking efficiency can be achieved. But remember, this requirement is for a laden trailer. When unladen, the brakes and rams will generate the same braking force, but on a vehicle weighing 70% less! A situation called 'over-braking' results, causing the trailer wheels to lock, rapid tyre wear and possibly trailer instability.

Load sensing

Load sensing provides a solution to the problem by adjusting the braking effort (actuator pressure) relative to the load being carried. A simple (hydraulic or pneumatic) valve senses deflection of the trailer suspension with load and reduces brake line pressure when partially loaded or unladen. Load sensing should always be specified for higher performance (50% efficiency) braking systems to avoid wheel locking and provide a controllable package.

Brake response time

An important factor in preventing tractor brake failure is to ensure the trailer is contributing to overall retardation as soon as possible. For example; when braking to decrease speed on a downhill run, the tractor brakes will start to retard the load immediately, taking the entire combination's kinetic energy until the trailer brakes respond. If trailer brake response time is good, the trailer system will contribute to tractor/trailer deceleration as quickly as possible, helping to prevent tractor braking system overload.

Hydraulic brake hose diameter

Pneumatic trailer brakes respond rapidly but hydraulic systems are believed to be slow. Hydraulic brakes have to push a cold column of oil along the trailer chassis right back to the axles. The usual $\text{\O}1/4$ " hose, fitted to keep costs down, restricts oil flow and increases brake response time. If larger rams are fitted to get more braking effort, greater oil volume will be required, further increasing brake response time.

Replacing the trailer hydraulic brake hose with a larger ($\text{\O}1/2$ ") size has been shown to dramatically improve brake response time to levels equivalent to air brakes!

Dual-line and failsafe

These features are required for trailers which are operated above 20 mph (32 km/h). Dual-line pneumatic braking systems already meet the requirements, but existing single-line hydraulic systems need modification to be legal (and safe!).

The law requires that the trailer brakes must automatically be applied if it accidentally separates from the tractor. Also, should the tractor brakes fail (e.g. the engine stops, a hose fractures), the driver must be able to apply the trailer brakes to bring the combination to a halt.

These requirements are usually met by placing a pressurised (oil or air) reservoir on the trailer. Should something go wrong, the stored pressure is triggered (automatically or by the driver) to apply the trailer brakes.

ABS

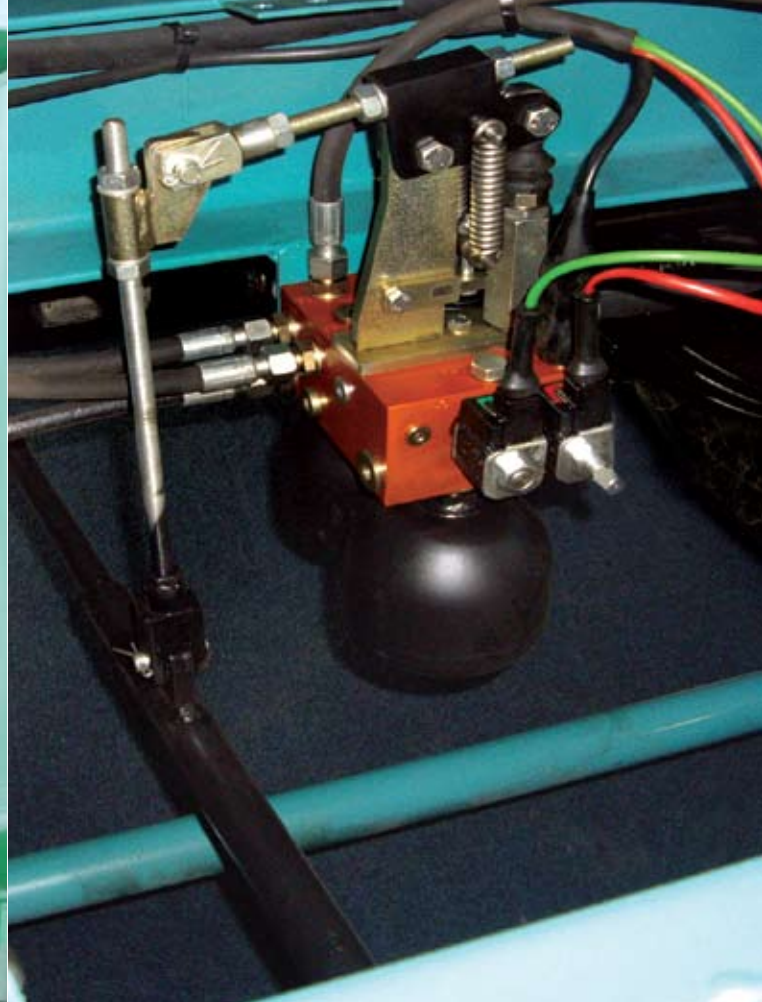
Antilock braking systems are designed to prevent wheel locking when braking on slippery surfaces. They are currently required on agricultural trailers used above 20 mph (32 km/h) because of commercial vehicle braking legislation. However, it seems unlikely that future EU Agricultural Braking Regulations will require trailer ABS at anything other than very high speeds.

Some consider ABS to be an acceptable substitute for load sensing as a means to avoid over-braking when unladen, but this is not the case.

The ABS system ends up trying to control an over-capacity (when unladen) braking system receiving full system pressure. Rather like trying to use a sledgehammer for cracking nuts. Load sensing reduces the size of the 'hammer' to more manageable proportions.



Pneumatic load sensing (Note: balance beam between axles and 'screw-type' slack adjusters)



Hydraulic combined load sensing/emergency fail safe valve (Note: balance beam between axles)

Maintenance

Braking system adjustment, to compensate for shoe lining wear, is often overlooked and is predominantly the root cause of trailer braking problems. It is important that system free-travel adjustment and lining inspection are carried out on a regular basis as this will have a significant effect upon braking performance.

As brake linings wear, system free-travel increases and the brake rams/actuators extend further to compensate. This increases trailer brake response time because the rams have to travel further to apply the brakes.

Most brake rams have approx. 75 mm available stroke. If lining wear increases free-travel to the point where the rams are fully-extended,

no force will be applied to the shoes and the vehicle will have no brakes. This then leaves the tractor to stop the entire load.

Regular trailer brake free-travel adjustment is vital if tractor brake failure is to be avoided. Use of under-sized foundation brakes at higher speeds may well increase shoe lining wear rates beyond those previously experienced. But regular adjustment is only likely to happen if it's easy to do, and often it isn't on older trailers.

A simple and cheap solution is to retro-fit manual 'screw-type' brake slack adjusters.

These replace the brake lever arms and incorporate an internal worm and wheel. Turning an external nut rotates the lever arm on the brake

camshaft and adjusts the system free-travel.

This is not a substitute for brake drum removal and lining inspection, but at least it ensures the brake shoes will actually be pushed onto the drums during braking.

Getting trailed equipment braking systems to “stop their weight”

Remember, a fully-loaded trailer can account for up to 75% of a tractor-trailer combination’s kinetic energy.

It is imperative that any trailed equipment has a braking system of the correct specification for the top speed travelled. It should also be maintained to ensure that it contributes appropriately to the overall braking effort of the combination, to prevent tractor brake overload.

Air brakes

Currently, pneumatic brakes give quicker brake actuator reaction times, making them more sensitive and easier to control than conventional, simple hydraulic brakes. They are also cleaner and cheaper to operate.

Air brakes are always used on commercial lorry trailers and may be the way forward for agricultural equipment.

However, upgraded hydraulic brakes can deliver comparable performance.

In summary

- Free-travel adjustment and shoe lining inspection. This will keep the brakes working at maximum efficiency and reduce response time to a minimum.
- Increase brake actuator ram size to give greater braking force.
- Fit screw type brake lever arms: this encourages and assists regular brake adjustment.
- Increase hydraulic brake hose diameter to improve system response characteristics.

- Load sensing – essential when increasing braking performance for higher-speed operation, if wheel locking and excessive tyre wear are to be avoided.
- Air brakes give quicker reaction times with greater control than current hydraulic systems, but hydraulic brakes can be comparable if specified correctly.



A joint pro-active approach to sales and service

To overcome this industry wide problem, we need a pro-active and joint approach from both sales and aftersales departments.

Think about...

The needs of your customer when selling a tractor or trailed equipment.

- 🍀 What speed is the customer's current tractor capable of?
- 🍀 Is the customer's current equipment capable of higher speeds?

Remember a new trailer is likely to outlast 2-3 replacement tractors over its 'frontline use' lifetime. Higher-spec. trailer brakes may cost more, but they will cost less to run and be much cheaper (and safer and legal) in the long run.

- ✔ Encourage the customer to add air brakes to new tractor and trailed equipment specifications, or upgrade existing hydraulic trailer brakes and supplement them with load sensing and failsafe systems.

- ✔ When selling 50 km/h tractors, offer to inspect and test the customer's current trailed equipment at the point of tractor installation.

- ✔ Advise on any necessary repairs or changes to specification required to prevent possible problems and comply with legislation. Document your findings and present solutions.

- ✔ During tractor and trailed equipment installation explain the implications of "over speeding" and the effects on tractor and trailed equipment braking systems.

- ✔ Offer maintenance plans to your customers for their trailed equipment fleet. Your customers have serviced their tractor but often overlook trailed equipment braking systems, which may be wearing faster than they think when used at higher speeds with newer tractors. Prevention is better than cure!

- ✔ Invest in the training and tooling available to test trailed equipment braking systems.

- ✔ Proactively market this service to your customers through your sales and service department – targeting 40-50 km/h tractor users.

“Thank goodness the brakes were serviced...”



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