EAGLE TUGS TT-SERIES AWD AIRCRAFT TRACTORS TECHNICAL BRIEF

PRESENTED BY:

EAGLE
THE POWER TO MOVE YOU
Why are Eagle aircraft tractors superior to any other tractor for aircraft towing?

**Commercial Products** – With 18 years of experience of continuous product improvements, Eagle aircraft tractors have unequalled reliability; which is reflected in the only 3-year/3,000 hr warranty on the market.

**All Wheel Drive (AWD)** – The unique AWD power train of the Eagle TT-series provides customers superior traction in all weather conditions. The TT’s equal weight distribution also provides more controlled steering at all angles.

**Designed as Aircraft Tractors** – Eagle aircraft tractors were designed from the ground up specifically to move aircraft. Most other tractors in the industry were designed to tow baggage or other GSE. Eagle Tugs designs its aircraft tractors using precise Drawbar Pull (DBP) calculations and testing, assuring that its aircraft tractors are rated correctly to move each load.
Aircraft Towing
Technical Brief

This Technical Brief explains the technical details behind the design features of Eagle aircraft tractors which make them superior for military aircraft towing:

1. **All Wheel Drive (AWD) vs. Rear Wheel Drive (RWD)** – Discusses the operational differences as they pertain to aircraft towing

2. **Drawbar Pull (DBP)** – Discusses how drawbar pull is calculated and how it applies to military aircraft towing. The proper method to DBP testing is also discussed.

3. **Aircraft Tractor vs. Baggage Tractor** – Discusses the operational differences between an Eagle aircraft tractor and a baggage tractor, and why Eagle aircraft tractors are the best option for military aircraft towing.
All Wheel Drive (AWD) vs. Rear Wheel Drive (RWD)

There are 2 major benefits to AWD aircraft tractors when moving aircraft:
1. AWD aircraft tractors provide superior traction on all surface conditions.
2. With equal weight distribution, there is no loss of steering with AWD aircraft tractors as with RWD tractors which tend to be too light in the front end.
Proper weight distribution above a tow tractor’s drive wheels is calculated as follows:

**RWD** – There must be an equal amount of weight over the tractor’s drive wheels as the required amount of Tractive Effort (TE) force. Also, in order maintain effective steering, the front steer-axle must weigh at least ½ the weight of the rear axle.

- A lineal pulling force of 8,800# TE multiplied by .9 COF = 8,000# DBP. So, in order to develop 8,000 lbs. DBP, a RWD tractor must weigh 8,800# over its drive wheels (rear axle only). Additionally, in order to maintain effective steering, the front steer-axle must then weigh 4,400#. **The result is that an 8000# DBP, RWD tractor must weigh 13,200#.**

**AWD** – Just as with RWD tractors, there must be an equal amount of weight over the tractor’s drive wheels as the required amount of Tractive Effort (TE) force. However, an AWD tractor’s weight is evenly distributed between the front and rear axles.

- An AWD aircraft tractor needs 8,800# over its drive wheels, but since both axles are drive axles, the total weight needed for an AWD aircraft tractor is 8,800#. Also, the weight to maintain effective steering is also accomplished with ½ the tractor’s weight over front steer-axle. **The result is that an 8,000 DBP, AWD tractor must only weigh 8,800#, or 1/3 less than a RWD tractor generating the same DBP.**
Proper weight distribution above a tow tractor’s drive and steer wheels also assure proper, safe steering.

- Most RWD tractors do not demonstrate the necessary 2/3 weight over the drive wheels, and 1/3 weight over the steered wheels, which at times may result in a lifting of the front steered wheels, and a loss of traction. Even with proper weight distribution, pushing at angles beyond 45 degrees with RWD tractors results in a right or left skid challenge, caused by the doubled weight of the rear drive axle. Due to the fact that the rear drive axle generates all of the Tractive Effort (TE), it tends to overpower the steering.

- AWD drive aircraft tractors exhibit none of these steering problems. With equal weight distribution over front and rear drive wheels, AWD aircraft tractors naturally overcome the resistance caused by turning an aircraft beyond 45 degrees.
Drawbar Pull (DBP) and Proper Testing

Eagle Tugs prides itself on its 35 plus years of designing and manufacturing tow tractors. This experience has helped us to design tow tractors that are weighted and powered appropriately to push or pull their required and marketed weights.

A key to our design is how we calculate our tow tractors’ towing capacities, by applying the SAE AIR 1316 specification to our Drawbar Pull (DBP) calculations, and the method we use to test the DBP capacities.

We calculate the true DBP capacity of our aircraft tractors and make sure the towing capacity we market for our tractors is true in all weather conditions, for all plausible surface grades, and for all potential weights of aircraft our tractor may move.

The testing method alone is crucial to determining a tow tractor’s actual towing/pushing capacity. It has been observed that many manufacturers use a jerk method which only demonstrates an immediate or one-time DBP capacity. They do this because they can generate a higher rating by jerking the load cell one time, using the inertia of the tractor to gain better results. This is not indicative of the tractor’s towing capacity in a real-life situation in which the load, such as an aircraft, can not be jerked forward or backward. The Eagle Tugs’ testing protocol requires a gradual and consistent application of power, while recording DBP, until wheel slip or torque converter stall is achieved, indicating maximum DBP on that surface.
# Drawbar Pull (DBP) and Proper Testing

SAE AIR 1316

## Gross Towed Weight - GTW

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Aircraft Wt.</th>
<th>Tractor Wt.</th>
<th>Total Load LBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Challenger 850</td>
<td>53,250</td>
<td>8,900</td>
<td>62,150</td>
</tr>
<tr>
<td>TT-8D</td>
<td>53,250</td>
<td>8,900</td>
<td>62,150</td>
</tr>
<tr>
<td>CRJ-500</td>
<td>80,750</td>
<td>13,350</td>
<td>94,100</td>
</tr>
<tr>
<td>TT-12D</td>
<td>80,750</td>
<td>13,350</td>
<td>94,100</td>
</tr>
</tbody>
</table>

## Drawbar Pull Requirement - DBP

<table>
<thead>
<tr>
<th>4% Initial Start</th>
<th>Grade %</th>
<th>DBP Req'd</th>
<th>Rolling Resist Factor</th>
<th>DBP Req'd</th>
<th>DBP Req'd LBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,486</td>
<td>0%</td>
<td>-</td>
<td>1.4%</td>
<td>870</td>
<td>3,356</td>
</tr>
<tr>
<td>2,486</td>
<td>1%</td>
<td>622</td>
<td>1.4%</td>
<td>870</td>
<td>3,978</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3,764</td>
<td>0%</td>
<td>-</td>
<td>1.4%</td>
<td>1,317</td>
<td>5,081</td>
</tr>
<tr>
<td>3,764</td>
<td>1%</td>
<td>941</td>
<td>1.4%</td>
<td>1,317</td>
<td>6,022</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
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<td>-</td>
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</tbody>
</table>

## Tractor DBP Available

<table>
<thead>
<tr>
<th>Tractor DBP</th>
<th>Tire Efficiency</th>
<th>Surface Efficiency</th>
<th>Net DBP Available LBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>6,685</td>
<td>100%</td>
<td>90%</td>
<td>9,000</td>
</tr>
<tr>
<td>6,685</td>
<td>100%</td>
<td>66%</td>
<td>5,887</td>
</tr>
<tr>
<td>6,685</td>
<td>100%</td>
<td>45%</td>
<td>4,000</td>
</tr>
<tr>
<td>13,333</td>
<td>100%</td>
<td>90%</td>
<td>12,000</td>
</tr>
<tr>
<td>13,333</td>
<td>100%</td>
<td>66%</td>
<td>8,800</td>
</tr>
<tr>
<td>13,333</td>
<td>100%</td>
<td>45%</td>
<td>6,000</td>
</tr>
</tbody>
</table>

**Surface Efficiency:**
- 90% - Dry Concrete/Asphalt
- 66% - Wet Concrete/Asphalt
- 45% - Snow/Ice with Cables
Aircraft Tractor Design

18 years ago, Eagle Tugs set out to design a tow tractor specifically to move aircraft. The only tractors in the industry at the time were general purpose tractors or baggage tractors.

The result of Eagle’s engineering is the AWD TT aircraft tractor (NSN 1740 01 461 4279). The features of the TT-series that set it apart from its competition:

- **AWD** – The only AWD aircraft tractor in its weight class
- **Low Profile** – Designed to fit under the wings of most aircraft.
- **Ergonomic Operation** – Slide in and out design. No climbing.
- **Visibility** – Hitch Sight Tunnels allow the operator to see both hitches at all times.
- **Reliable** – The only tow tractor in the industry with a 3-year/3,000 hr warranty

On Reliability, First Sergeant JT Lee, 160th SOAR:
“Right now we’re getting around 2,500 hours between failures and I think the only thing we’ve had to do on it besides oil changes and changing filters is to replace a steering hydraulic pump. They could probably last forever.”
Aircraft Tractor Design

Aircraft tractor design versus standard (baggage) tractor design conclusions:

- Standard (baggage) tractors are intended to pull carts, not multi-million dollar aircraft. These are clearly two different operations with separate sets of requirements.
- Standard (baggage) tractors compete in a very price competitive market, in which manufacturers have to control costs in order to compete. This formula does not work when you try to apply it to moving aircraft, in all weather conditions, day in and day out. Lower cost components, when used at their maximum capacity for prolonged use, are much less reliable.
- Aircraft tractors, designed specifically to move aircraft, with towing capacities directly matched with the weight of the aircraft, are much more efficient, safe and reliable.
- Not only do the features of AWD aircraft tractors provide operators the proper equipment to safely and efficiently accomplish their jobs, the added reliability alone makes Eagle AWD aircraft tractors the right choice for moving military aircraft.
## Aircraft Tractor Design

<table>
<thead>
<tr>
<th></th>
<th>Eagle AWD Aircraft Tractors</th>
<th>Standard (Baggage) Tractor</th>
<th>The Eagle Aircraft Tractor Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Wheel Drive</td>
<td>Only AWD tractors in 4,000-12,000 lb DBP</td>
<td>Not required, too expensive for pulling baggage</td>
<td>AWD provides controlled traction on all surfaces/Lighter weight</td>
</tr>
<tr>
<td>Low Profile</td>
<td>Only 38-48 in. tall</td>
<td>55-60 in. or taller</td>
<td>Better for maneuvering around aircraft. Less chance for accidental damage to aircraft</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>Slide in and out, ergo design</td>
<td>Climb up and down, strain on operator</td>
<td>Mid-operator, w/ low profile design, allows for easy ingress/egress</td>
</tr>
<tr>
<td>Visibility</td>
<td>Direct front/rear hitch/nose wheel vision through sight tunnels</td>
<td>No front hitch vision, must use mirrors</td>
<td>Direct operator visibility for safer, more efficient operation</td>
</tr>
<tr>
<td>Tire Size/Steering</td>
<td>Same size front and rear tires with equal weight distribution</td>
<td>Large rear and small front tires, often too light in the front end</td>
<td>Same size tires/Equal weight distribution allow for controlled steering when moving aircraft</td>
</tr>
<tr>
<td>Reliability</td>
<td>Properly selected power train relationships</td>
<td>Cost competitive market, must use lower cost components</td>
<td>Proprietary power train component relationship results in smooth operation and reliability</td>
</tr>
</tbody>
</table>
Aircraft Tractor Design

Example of low profile design and direct hitch view of the Eagle AWD TT-series

Example of the ergonomic design (easy ingress/egress) of the Eagle AWD TT-series

Examples of standard (baggage) tractors which have no ergonomic design and no clear view of hitches
Conclusion: Unique Features of TT-Series Aircraft Tractors

The unique features of TT-series aircraft tractors:

- Come with the only 3-year/3,000-hour warranty in the industry
- All Wheel Drive for smooth, controlled pushback in any weather condition
- Low-profile design for use with regional, corporate & military aircraft
- Ergonomically superior
- Mirror-less hitch visibility
- Reliable, comfortable and safe to use
- Low cost of ownership
- Outstanding factory direct service and support
- A proven global history of dependability
### Representative List of Eagle Tugs’ Customers

#### AIRLINES
- American Eagle
- Atlantic Southeast
- Canadian Air
- Comair
- Delta Connection
- Flagship
- Midwest Express
- Skywest
- Southwest
- United Express
- Voyageur Airlines

#### AIRCRAFT MANUFACTURERS
- Boeing
- Bombardier
- Cessna Aircraft
- Dassault Falcon Jet
- Fairchild Aircraft
- Gulfstream Aerospace
- Honeywell
- Jetstream Aircraft Ltd.

#### CONTRACT GROUND SUPPORT
- Worldwide Aviation Services
- Signature Flight Support
- Globe Ground Services
- Menzies
- ASIG
- Swissport

#### GOVERNMENT & MILITARY
- Federal Aviation Administration
- Kennedy Space Center
- U.S. Coast Guard
- New York City Police Dept.
- City of New York - EPA
- Alaska Air National Guard
- Michigan Air National Guard
- Canadian Defense Forces
- Transport Canada
- U.S. Army
- U.S. Air Force
- U.S. Marshall Service
- Turkish Air Force (TUAFL)
- Turkish Land forces
- Pakistan – Navy
- Romania – Army Land Forces
- Royal Saudi Air Force
- U.A.E. Air Force

#### FBO, CHARTER, CORPORATE AIRCRAFT DEPARTMENTS
- Allied-Signal
- Amway-Alticor
- Anadarko Petroleum
- Aviation Methods
- Beckair
- Boise Executive Hangar
- Caterpillar
- Colorado Jet Center
- Columbia Air Services
- Corning
- Dryden Air Services
- Duncan Aviation
- Eaton Corp.
- Executive Jet
- Goodyear
- GTE
- Home Depot
- Jet Corp.
- Kal-Aero (Duncan)
- Masco
- Maytag
- Million Air
- Nordstrom
- Northern Air
- Pan Energy
- Rotor's In Motion
- S.C. Johnson Wax
- Santa Fe Jet Center
- Signature Flight Support
- Sun Valley Aviation
- Texas Aero
- Vail Valley
- VF Corporation
- Irving Oil
Presented by: Justin Akinleye - Director of International Sales

Manufactured in Greater Detroit:
Eagle Tugs
26111 Northline Rd
Taylor, MI 48180 USA

Global Sales Office:
Eagle Tugs
Maple House
High Street
Potters Bar
Herts, EN6 5BS
UK

www.eagletugs.com