Bollard Pull

(Capt. P. Zahalka, Association of Hanseatic Marine Underwriters)

Bollard Pull is, the tractive force of a tug, expressed in metric tonnes (t) or kN.

This figure is not accurately determinable by mathematical methods, therefore it must be evaluated for each tug by a “Bollard Pull - Test“.

Although primarily dependent on the tug’s engine output expressed in BHP (Break Horse Power or MCR (Maximum Continuous Rating) or DIN 6270, output "A"), also some other factors, like:

- propeller-type
- kort nozzle (yes/no)
- shape of the hulls submerged part
- draught
- trim

become important regarding the achievable the Bollard Pull.

As a rules of thumb for an approximately conversion from BHP to "t" of the effective available Bollard Pull the following formulas may apply:

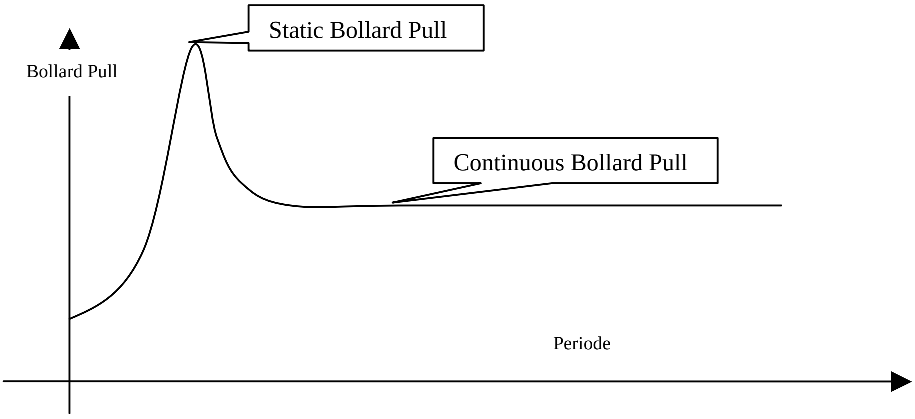
Tug equipped with fixed pitch propeller: (freewheeling)	BHP x 0,9 x 1,10 / 100 = (t)
Tug equipped with fixed pitch propeller and kort-nozzle:	BHP x 0,9 x 1,20 / 100 = (t)
Tug equipped with controllable pitch propeller: (freewheeling)	BHP x 0,9 x 1,25 / 100 = (t)
Tug equipped with controllable pitch propeller and kort-nozzle :	BHP x 0,9 x 1,40 / 100 = (t)

The resulting values have to be regarded as rough estimates and might be variable, depending on parameters of ship’s construction. Nowadays this applies all the more as there is a variety of different types of propulsion systems which might provide different amounts of Bollard Pull defiant of equal engine performance.

In general the Bollard Pull - Test is carried out by steaming into a towrope which is fixed ashore and connected to a measuring device, successively with three different performance-level (80%, 100% and overload = 110%).

Very important fort the performance of the Bollard Pull - Test is the location. A sufficient sized tideless sheet of water with a depth of not less than 20m is needed. The length of the towrope is also essential because the propeller stream has to develop without interference by reflection at the quaywall.

The achieved traction force is described as the “Continuous Bollard Pull” and has to differentiated from the so called “Static Bollard Pull“.

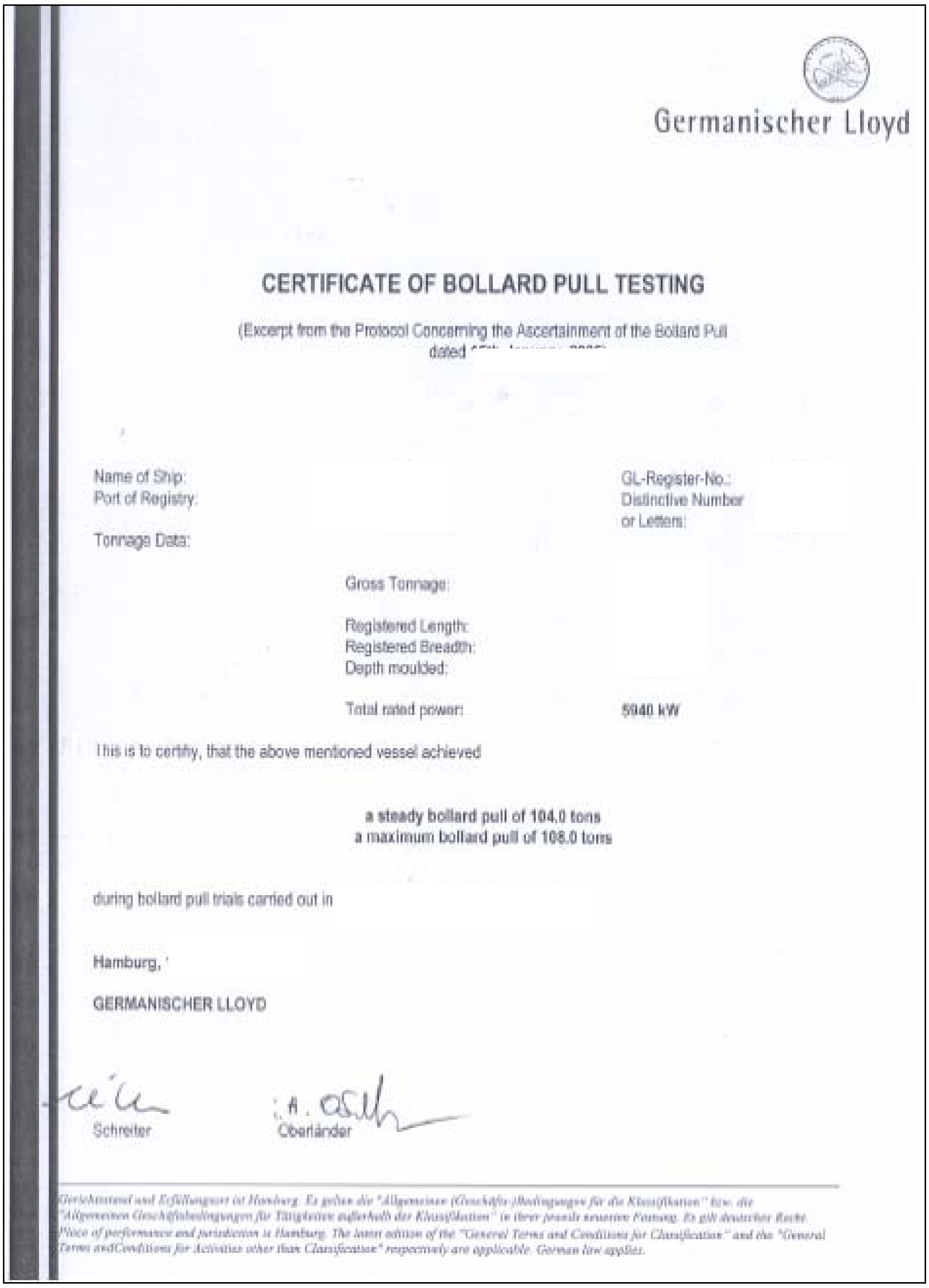


The “Static Bollard Pull“ also called “Maximum Bollard Pull“ is achieved shortly after the commencement of the Test, when the Propeller is working in still water and full power is achievable. Once the water is streaming through the propeller the performance decreases e.g. to the effect of cavitation and propeller slip. The remaining traction force is named “Continuous Bollard Pull“ or also “Steady Bollard Pull“ and is measured for a period of about 10 minutes.

The result of the achieved traction force of the tug at different performance-levels of propulsion will be certified and an of Bollard Pull certificate will be issued.

In general the testing institution is the classification society of the vessel.

e.g.:



Germanischer Lloyd

CERTIFICATE OF BOLLARD PULL TESTING

(Excerpt from the Protocol Concerning the Ascertainment of the Bollard Pull dated

Name of Ship:
Port of Registry:

GL-Register-No.:
Distinctive Number or Letters:

Tonnage Data:

Gross Tonnage:

Registered Length:
Registered Breadth:
Depth moulded:

Total rated power: 5940 kW

This is to certify, that the above mentioned vessel achieved

a steady bollard pull of 104.0 tons
a maximum bollard pull of 108.0 tons

during bollard pull trials carried out in

Hamburg,

GERMANISCHER LLOYD

Schreiter   Oberländer

Gerichtsstand und Erfüllungsort ist Hamburg. Es gelten die "Allgemeinen (Geschäfts-)Bedingungen für die Klassifikation" bzw. die "Allgemeinen Geschäftsbedingungen für Tätigkeiten außerhalb der Klassifikation" in ihrer jeweils neuesten Fassung. Es gilt deutsches Recht. Place of performance and jurisdiction is Hamburg. The latest edition of the "General Terms and Conditions for Classification" and the "General Terms andConditions for Activities other than Classification" respectively are applicable. German law applies.

Detailed information could be learned from the record of the test if required.

It is not difficult to imagine that these figures are idealized. In practise following losses have to be borne in mind:

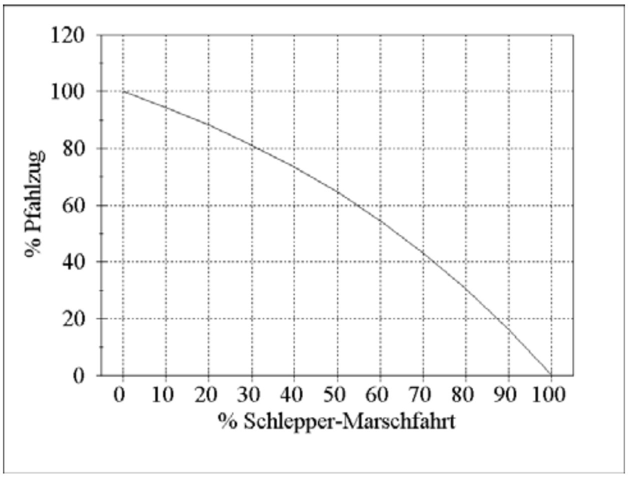
1) During a tow it is not possible to maintain 100% power of the main engine for a long period without a development of thermal problems. Therefore it makes sense to take the nominated BHP (Break Horse Power or MCR (Maximum Continuous Rating) or DIN 6270, output "A") of the tug in consideration at 90% only .

2) Keeping in mind that Bollard Pull test results have been determined at "0" speed of the tug, it is understandable, that these results wouldn't have been attained on a tug which would make some speed through the water on his own. Every speed made (and thereby overcoming hydro- and aerodynamic resistance) will consume energy or engine power.

In other words: For the achievement of Bollard Pull on a vessel making speed through the water on her own, always only as much power is at disposal as is not needed for making this speed.

"0" Speed through Water = 100% Bollard Pull
max. Speed through Water = "0" Bollard Pull

The following curve shows, in adequate precision, tugs own speed related to possible Bollard Pull.



3) Other factors affecting the development of Bollard Pull in a harmful way are:

- Roughness of the underwater body of the tug (marine fouling),
- pitching, rolling and heaving of the Tug (sea conditions),
- high seawater temperature (ME- cooling water problems)

For the process to determine the necessary Bollard Pull for a specific towing task the above restrictions have to be kept in mind.

We have now arrived at the following question:

How much Bollard Pull is necessary?

Surely this is one of the most interesting questions in connection with this matter, but also one difficult to answer, too.

The Bollard Pull in conjunction with a specific object to be towed must be assessed to:

- obtain the pre-planed towing-speed,
- provide sufficient power-reserve to ensure safety of the tow also in unfavourable current- and weather conditions.

So, sufficient energy must be provided to overcome the resistance occurring at a swimming body making speed through water.

This resistance is made up of several components:

Simplified these aret:

1) Hydrodynamic resistance	at the Vessel
	at the towing gear
2) Aerodynamic resistance	at the vessel

This two values are in turn depending on other parameters as e.g. sea state, wind direction, wind speed, size of the topside facing vertical to the wind direction, yawing and pitching of the object, towing speed through water, roughness of the underwater body, size and amount of propeller, etc.

To estimate the necessary value of Bollard Pull several rules of thumbs exists, which all have an empirical history.

For this purpose the VHT uses a self developed calculation scheme which includes both empirical as pure mathematical/physical components. This scheme provides values which have been approved in practice and still include a reasonable safety margin.

See the following example:

Calculation of the required Bollard Pull to tow ship shaped
Verschleppung von schiffsförmigen Anhängen

ANNEX:	**MS**	**Example**	**Type:**	**Container**	
length o.a.	**(L)**	**160,00**	**m**		
length p.p.	**(Lpp)**	**151,00**	**m**		
width	**(B)**	**17,20**	**m**		
Superstructure height	**(Ah)**	**12,00**	**m)**	**Bear in mind**	
superstructure length	**(Al)**	**130,00**	**m)**	**possible**	
Superstructure width	**(Ab)**	**15,00**	**m)**	**Deck load**	
Height (main deck-lower keel)	**(Sh)**	**15,00**	**m**		
draught	**(T)**	**8,20**	**m or**	**26,90**	**ft**
Displacement, seawater		**13.750,00**	**to**		
Displacement/Volume	**(D)**	**13.414,63**	**cbm**		
Block-Coefficient	**(a)**	**0,63**			
wetted submerged area	**(S)**	**3.834,39**	**qm or**	**41.274,41**	**qft**
propeller diameter		**4,00**	**m or**	**13,12**	**ft**
number of propeller		**1,00**			
yawing-angle	**(b)**	**5,00**	**°**		
wind-angle	**(g)**	**25,00**	**°(enter 0°-180°)**		
wind-speed	**(Vw)**	**5,00**	**BFT.**		
without air stream		**20,79**	**kn**	**10,69**	**m/sec**
incl. air stream		**25,79**	**kn**	**13,27**	**m/sec**
air density	**®**	**1,22**	**kg/cbm**		
Shape-Coefficient (hull)		**1,00**			
Shape-Coefficient (superstructure/cargo)		**1,20**			
Vertical area facing the wind		**1.552,71**	**qm**		
Day since last dry-docking		**150,00**	**Tage**		
Sea margin		**0,15**		**see ====>>**	
Speed over ground		**5,00**	**kn**	**2,57**	**m/sec**
Stream („-„ if following)		**0,50**	**kn**	**0,26**	**m/sec**
Speed through water	**(v)**	**5,50**	**kn**	**2,83**	**m/sec**
hydrodynamic towing resistance	**(Rh)**	**20,22**	**to**		
aerodynamic					
towing resistance	**(Ra)**	**15,55**	**to (following)**		
friction					
due to fouling	**(Rf)**	**5,50**	**to**		
Hydrodynamic resistance					
of Towing gear	**(Rg)**	**0,50**	**to (lump)**		
Calculated total - towing resistance of tow	**(Rt)**			**41,77**	**to**

To achieve at gale force:	**5,00**	**BFT the theoretical towing speed (v)**		
of:	**5,50**	**kts through water, the**		
		certified Bollard Pull (BP) of the		
Tug at 100% Engine Power must be		**46,00**	**tonnes**	
equal to BHP-need of:		**3.868,00**	**BHP (about)**	
Tugs standard cruising speed (v2):		**14,00**	**kts**	
It is recommended to use a tug with a				
certified bollard pull of:			**50,00**	**tonnes.**

You will have noted that we regard the calculated total resistance to be equal to 90 % of the necessary towing force and thus ascertain the required certified Bollard Pull at 100% Engine Power as follows:

$$41{,}77 \div 90 \times 100 = 46{,}00$$

Classification societies, also issuing Towage Approval Certificates, are dealing with this problem as follows:

e.g. Germanischer Lloyd:

Quote

The towing force is to be ascertained with due allowance for the tow, the route, the duration of the voyage and the weather and sea state proper to the time of the year. A general reference may be taken as the power by which a tug is able to keep the tow in position with ahead wind of v = 20 m/s = Bft. 8-9 and a head current of v = 1 m/s.
(This reference value is not to be interpreted to mean that a tug and tow drifting astern under the effect of higher winds and wave drifting forces in the open sea is exposed to danger. Controlled drifting in the open sea is generally to be regarded as acceptable. In tug service it is normal practise for a towing train to drift under appropriate current and weather conditions.)

Unquote

Assuming such environmental conditions the required Bollard Pull in the above example would be 65 tonnes. However winds of Bft 9 not coming from ahead but from up to maximum 25° off the bow (counted from ahead) were taken into consideration in this case.

Different procedures of other classification societies could provide other values also used in the towing industry. Values determined by using the VHT calculation scheme are throughout still include a reasonable safety margin.

Calculations of the Bollard Pull required for a specified towing operation in a specified sea area during a specified season aren't, as said before, an accurate science although with some efforts good results are achievable.

The towing industry often works on the basis of experience and it seems that many different people made plenty different experiences. This is indicated by the variety of formulas and recommendations which have been developed empiricly over time.

Like aforesaid, the VHT developed his own scheme, correlating with values out of praxis quite satisfactory.

Some other formulas and recommendations known to me I will name here, to provide the reader with the possibility to compare and judge on his own:

1. Rough calculation of required Bollard Pull in case of ship-shaped tows:

$$R = \frac{2,5(R_1 + R_2 + R_3)}{2240}$$

$R_1 = F \cdot S \cdot V^2$	F	=	0,01
	S	=	wetted underwater area in ft²
	S	=	$1,025 \cdot L_{pp} \cdot (C_B \cdot B + 1,7 \cdot T)$ (m²)
	Lpp	=	Length between perpendiculars (m)
	T	=	Draught (m)
	B	=	Width (m)
	Cb	=	Block-Coefficient
	feet²	=	m²·10,764262
	V	=	Towing speed in knots
$R_2 = D^2 \cdot V^2 \cdot N$	D	=	propeller diameter of the tow
	V	=	Towing speed in knots
	N	=	Number of Propeller
$R_3 = 0,1 \cdot R_2$	R_3	=	Coefficient for resistance of towing gear

By using this formula, which is providing a Bollard Pull value corresponding with the hydrodynamic resistance of the ship in calm waters, bear in mind that other factors like roughness of the submerged area, yawing of the tow, aerodynamic resistance and sea state are disregarded. A factor of 2 - 3, depending to the circumstances, seems adequate.

2. Following formula allows a rough calculation of BHP (Break Horse Power):

$$BHP = D2/3 \times v^2 \div 120$$

D	=	Displacement of the tow (t)
v	=	towing speed in knots

BHP calculated by using the above formula have to be divided by 100 and multiplied by 1,4. The result will be the required Bollard Pull in “t” for a tug with controllable pitch propellers in Kort nozzles (see page 1).
In case non shipshape tows are involved it might be necessary to double the determined values.

3. Another formula to roughly determine the requested Bollard Pull under consideration of aerodynamic resistance and Seas state:

$$Bollard - Pull = \left[\left(D^{2/3} \times v^3\right) \div 7200 + \left(C_{mw} \times B \times D_1\right)\right] \times K$$

D	=	Deplacement of the tow (t)
v	=	Towing speed in knots
C_{mw}	=	coefficient for the mean wind speed
B	=	Width of the tow (m)
D_1	=	Height of the wind facing area above water level, incl. Deck cargo (m)
K	=	Factor 3 - 8, depending to the circumstances

This formula should only be used during following two situations:

- Ordinary towing conditions (BFT. 4)

V = 6 knots
C_{mw} = 0,0025
K = > 3

- Keep on station during heavy weather (BFT. 10-11)

V = 3 knots
C_{mw} = 0,015
K = 8

4. A simplified formula for the rough calculation of required Bollard Pull reads as follow:

$$Bollard - Pull(t) = \frac{Deplacement(t) \times 60}{100.000} + 40$$

In this case the minimum Bollard Pull is ascertained by the summand 40, therefore for smaller tows, requiring less than 40 t of Bollard Pull, this formula is not applicable.

Comparing the above Formulas with the VHT calculation shoes the following picture:

VHT	46 t	
Formula 1	48 t	Factor 3
Formula 2	32 t	
Formula 3	49 t	C_{mw} = 0,0025 K = 3,5
Formula 4	48 to	

So the recommendation to use a tug providing 50 t Bollard Pull is adequate.