Alternate Compliance Rating for

Millennium 105'-Class and Z-Class ASD Tractor Tugs

for San Francisco Bay Tanker Escort

Prepared for

Harley Marine Services, Inc.

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David L. Gray, P.E.
Project Manager

SUMMARY

The California Code of Regulations (Ref. 1) gives a default matrix option for matching tugs to tankers (see Table 1). These minimum requirements have been established based on the tanker demand to stop the escorted tanker from 5 knots speed through the water (STW) in the event of a propulsion failure. The escort tug is required to have sufficient braking capability to match this demand. The braking capability for a conventional tug and for Azimuthing Stern Drive (ASD) type tugs is to be taken as its astern bollard pull and that for a VSP-type tractor tugs is to be taken as its ahead bollard pull.

The method of defining the braking capability as the bollard pull of the escort tug does not account for the increased braking force that a tractor tug is capable of applying at higher speeds nor does it account for the degradation in braking performance for a conventional tug at higher speeds. Thus, a tractor tug and a conventional tug demonstrating the same degree of compliance with the rules may have a significant disparity in braking capabilities at the actual transit speeds through the Bay (10 knots in zones 1, 2 and 8 knots in zones 4, 6).

This report gives an evaluation of the stopping performances of the Millennium 105' and Z-Class tugs when they are applied to a range of tanker sizes after a propulsion failure at the actual speeds of transit in San Francisco Bay. The results are then compared to the action of a 'minimum compliance tug', a hypothetical tug which has just sufficient bollard to meet the demand in the default matrix but is nevertheless incapable of applying forces above 5 knots. Based on this comparison, alternate ratings are proposed for the Millennium 105' and Z-Class tugs in the two escort zones (Table 2). These ratings are, in fact, equal to the predicted braking forces of the tug at a steady speed of 10 knots for zones 1, 2 and 8 knots for zones 4, 6. The tug force predictions are subject to the following:

- [a] The escort tug is not required to exceed the limits of its ability to generate the forces. The capability is subject to a heel limit established as geometrical submergence of the main deck edge.
- [b] The escort tug operates all its equipment in conformity with recommended guidelines published by the manufacturer for the safe working load of the vessel.
- [c] All machinery is assumed to operate at the rated performance levels published by the manufacturer.
- [d] The astern bollard of the Millennium 105' and Z-Class Tugs is given in Table 2. This is the bollard pull used in the calculations.
- [e] Conditions that would impair the escort tug's ability to perform, such as tow line interference with the wheelhouse, and deck edge submergence, are considered.

Matching the Millennium 105' and Z-Class tugs using the alternate rating to the default matrix in the regulations results in shorter overall stopping distances compared to the 'minimum compliance tug' which can apply braking forces only after the tanker has coasted to 5 knots.

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INTRODUCTION

The California Code of Regulations (Ref. 1) gives a default matrix option for matching tugs to tankers (see Table 1). These minimum requirements have been established based on the tanker demand to stop the escorted tanker from 5 knots speed through the water (STW) in the event of a propulsion failure. The escort tug is required to have sufficient braking capability to match this demand. The braking capability for a conventional tug and for Azimuthing Stern Drive (ASD) type tugs is to be taken as its astern bollard pull and that for a VSP-type tractor tugs is to be taken as its ahead bollard pull.

The method of defining the braking capability as the bollard pull of the escort tug does not account for the increased astern force that a tractor tug is capable of applying at higher speeds nor does it account for the degradation in braking performance for a conventional tug at higher speeds. Thus a tractor tug and a conventional tug demonstrating the same degree of compliance with the rules may have a significant disparity in braking capabilities at the higher transit speeds through the bay (10 knots in zones 1, 2 and 8 knots in zones 4, 6).

A method of defining speed-dependent braking capabilities for tractor and conventional tugs which accounts for the variation of the braking force as a function of speed was developed and validated in the San Francisco Bay Tanker Escort Study (Ref. 2). Approximate capabilities of selected San Francisco Bay tugs for transit speeds of 6, 8 and 10 knots through the water were also given. These capabilities were then matched with tanker demands at the same speeds to arrive at viable escort solutions.

The default matrix option in the California Code of Regulations is based on a similar matching. However, the speed at which this matching is done is 5 knots. The capabilities of the tugs at low speeds are reasonably represented by the astern bollard in case of conventional tugs or the ahead bollard in case of tractor tugs. Hence, it was required that the bollard be used to match the demands. Any tanker-tug combination in exact compliance with the default matrix can be expected to produce roughly identical stopping performances from 5 knots under postulated failure and assistance scenarios. However, the performance of the tanker-tug combinations will differ if stopping from the transit speeds of 8 and 10 knots is considered. A tug capable of applying larger braking forces at the higher speeds will stop the tanker in a shorter distance and thus provide a superior level of stopping performance than a 'minimum compliance tug' which can only apply forces at 5 knots or less although both combinations provide the same level of compliance.

In this work, we have used the astern braking forces of the Millennium 105' and Z-Class tugs at the actual transit speed instead of the astern bollard to match the demands in the default matrix. We have then shown, through a set of calculations, that such matching will result in shorter overall stopping distances compared to the 'minimum compliance tug' defined here to be a hypothetical tug incapable of applying forces above 5 knots. All calculations were based on one-dimensional straight line coasting and stopping models. In reality, tankers will not follow a straight path either when coasting or when stopping under the action of a braking force. Nonetheless, the straight line approach provides a simple and a reasonable method of comparing the relative stopping performances of different tanker-tug combinations. The one-dimensional dynamic equations of motions used in the present calculations are the same as those used for stopping calculations in Ref. 2 and are given in Appendix C of Ref. 2. All speeds indicated in this report are those measured through the water unless stated otherwise.

CALCULATION OF MILLENNIUM 105' AND Z-CLASS TUGS CAPABILITY

The calculation of the braking force at speed for the Millennium 105' and Z-Class tugs, was done using Glosten's simulation software **Tug.Master** for ASD and Voith-Schneider tractor tugs. For a given hull and propeller combination, equations must be entered in the program describing the forces produced by the hull and thruster over the range of speeds and drift angles. The principle dimension of the two classes of tugs are given in Table 1.

BRAKING FORCE OF MILLENNIUM 105' AND Z-CLASS TUGS AT SPEED

The braking force predictions for the Millennium 105' and Z-Class tugs at 8 and 10 knots are given in Table 2. These forces are in tanker coordinates, and are based on direct (reverse arrest) mode braking at low speeds and indirect mode braking at higher speeds with the objective of maximizing the braking force with no regard to any associated steering component. The predictions plotted as a function of tanker speed are shown in Fig. 2. The steering component associated with maximum braking is small and can be nullified in operation by 'fishtailing' from side to side behind a tanker.. The prediction procedure involves a quasi-static analysis which takes into account the hydrodynamics of the underwater hull with skeg, rudder, etc., propeller characteristics, stability issues like freeboard and metacentric height, and other factors.

The predicted forces are then used to match the demands given in the default matrix reproduced here in Tables 3 and 4. The result of such matching is also indicated in Tables 3 and 4. These tables show the tanker sizes that the Millennium 105' and Z-Class tugs can escort.

STOPPING DISTANCE WITH MILLENNIUM 105' AND Z-CLASS TUGS

Tables 5 and 6 give the computed stopping distance from the actual transit speed (8 or 10 knots) using the Millennium 105' and Z-Class Tugs. The empty cells indicate cases for which the alternate compliance rating at speed is insufficient to meet the demand in the default matrix. These calculations have assumed an untethered escort mode and have taken into account a 2 minute time delay to make up lines. For tethered escort, the stopping distances will be shorter than those shown. However, the assumption of tether or untethered escort does not affect the determination braking force at transit speed and does not affect the alternate compliance escort rating.

The calculations also include a 20 knot astern wind.

EFFECTIVE STOPPING DISTANCE WITH THE 'MINIMUM COMPLIANCE TUG'

A 'minimum compliance tug' is defined as a hypothetical tug which has just sufficient bollard pull to meet the demand in the default matrix but is incapable of applying forces above 5 knots. To stop a tanker which has lost power going 8 or 10 knots, this hypothetical tug will be assumed to apply zero braking force at speeds above 5 knots and a constant force equal to its astern bollard at speeds less than 5 knots. Thus the effective stopping distance is obtained as the sum of the distance it takes to coast from 8 or 10 knots to a speed of 5 knots and the stopping distance from 5 knots to zero speed over ground. These coasting distances are given in Table 7 and the stopping distances in Table 8. The effective stopping distance with the 'minimum compliance tug' is then obtained as the sum of the corresponding coasting and stopping distances and is shown in Table 9.

The stopping distances are calculate to bring the tanker to a stop with respect to the ground (as would be required to prevent an allision or grounding). The cases with assisting currents (2 and 4 knots in Zones 1, 2, 4 and 6) require that the vessel be pulled stern first through the water at speeds of 2 or 4 knots so that over the ground speed is zero. The braking capabilities of the tugs are determined based on the through-the-water speed, as these are the flow conditions affecting tug performance. Ship speed is considered to be their through-the-water speed.

COMPARISON OF STOPPING DISTANCES

Table 9 gives the effective straight line stopping distance from transit speed with a 'minimum compliance tug' whereas Tables 5 and 6 give the straight line stopping distance with Millennium 105' and Z-Class tugs. A cell by cell comparison now shows that in every case, the stopping distance with the Millennium 105' and Z-Class Tugs is less than the effective distance with the 'minimum compliance tug'.

Tables 10 and 11 give the ratios of the stopping distances in Tables 5 and 6 to the corresponding stopping distance in Table 9. Values greater than 1 indicate that matching the Millennium 105' and Z-Class Tugs based on braking force at speed results in shorter stopping distances compared to the 'minimum compliance tug' if initial speeds of 10 and 8 knots are considered.

CONCLUSIONS AND LIMITATIONS

The results of this study should be understood, interpreted and used in the context of all the assumptions incorporated, and the failure and assistance scenarios postulated. In particular, the following points should be noted.

1. In this study, we have verified the result of matching the Millennium 105' and Z-Class tugs using its braking force at speed against the performance of a 'minimum compliance tug' which can clutch-in only at 5 knots when applied to a tanker which has lost power traveling at initial speeds of 8 or 10 knots. The objective was not any absolute level of safety but rather only a relative level of stopping performance.
2. The 'minimum compliance tug' defined in Section 4 is capable of stopping the tanker from 5 knots within the 95th percentile constraint but it is not capable of stopping the tanker from the speed of transit within that constraint (10 knots in zones 1, 2 and 8 knots in zones 4, 6). The proposed alternate rating for the Millennium 105' and Z-Class tugs results in a shorter overall stopping distance compared to the 'minimum compliance tug' when the speed from which the tanker is to be stopped is 10 knots in zones 1, 2 and 8 knots in zones 4, 6. This is shown schematically in Fig. 1.
3. This study has only addressed the stopping requirement in the California Code of Regulations. It has not addressed the ability of the selected escort tug to steer the tanker after a rudder failure. However, in our previous study (Ref. 6), the stopping requirement has been found to govern over the steering requirement in general when the effect of the tanker backing its own propeller is also considered.

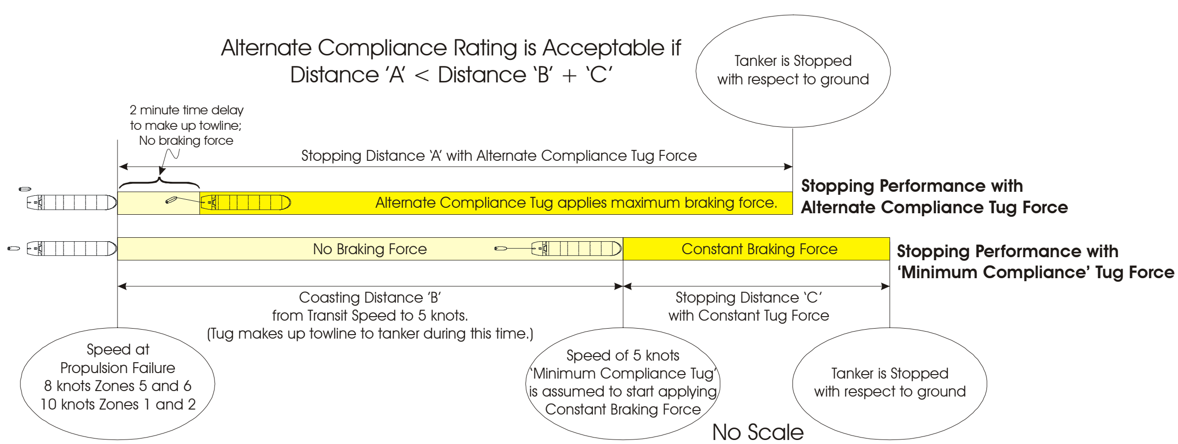

Fig. 1 Schematic of Stopping Calculations for Propulsion Failure

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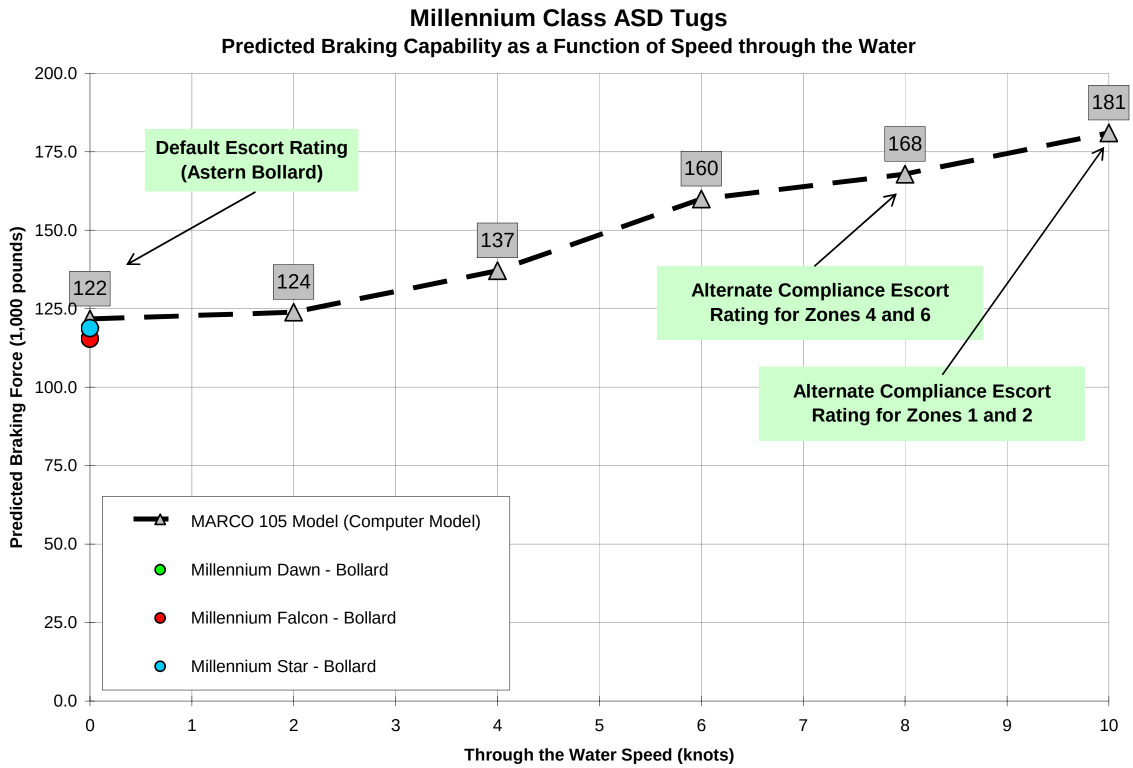
Table 1: Particulars of the Calculation Model for the Millennium 105' and Z-Class Tugs

	Millennium 105' Class	Z-Class	Units
LOA	105'	94'	feet
LWL	100.4'	89.1'	feet
Beam	34'	32'	feet
Draft	14.8'	11.4'	feet
Bollard ahead	127,900 lbs	110,400 lbs	average of 3
Bollard astern	121,700 lbs	105,200 lbs	average of 3
Engines	CAT 3516B	CAT 3516	(2)
Max. RPM	1600	1600	
Nominal HP	4400	4000	total
RPM Ratio	6.42	5.515	Engine to Propeller
Propellers	4-blade in nozzles	4-blade in nozzles	Azimuthing
Diameter	94.5"	86"	inches
Pitch	92.7"	81.1"	inches
P/D ratio	.981	.943	
Displacement	685.6	408	long tons
Stillwater Freeboard	4.2'	1.4'	feet
GM	6.0’	8.6'	feet
Hull Lat'l Area	898	666	ft^2
Skeg Lat'l Area	180	93	ft^2

Table 2: Braking Force Capabilities of Millennium 105' Class and Z-Class Tugs at Escort Speed of 8 and 10 knots

Tug	Measured Ahead Bollard Pull (kips)	Measured Astern Bollard Pull **Default Rating** (kips)	Computed Braking Force at Steady Speed (kips) Alternate Compliance Rating	
			8 kts (Zones 4 & 6)	10 kts (Zones 1 & 2)
Millennium Falcon	125.9	**115.4**		
Millennium Star	129.2	**118.8**		
Millennium Dawn	128.5	**131.0**		
Average ⇨	127.9	**121.7**	**168**	**181**
Z THREE	107.3	101.5		
Z FOUR	112	107		
Z FIVE	112	107		
Average	110	**105**	**135**	**132**

Measured bollard pull values ahead and astern provided by Harley Marine. The bollard pull test for the *Millennium Falcon* was performed on 1/9/2003. Test locations and dates for the other vessels were not provided.



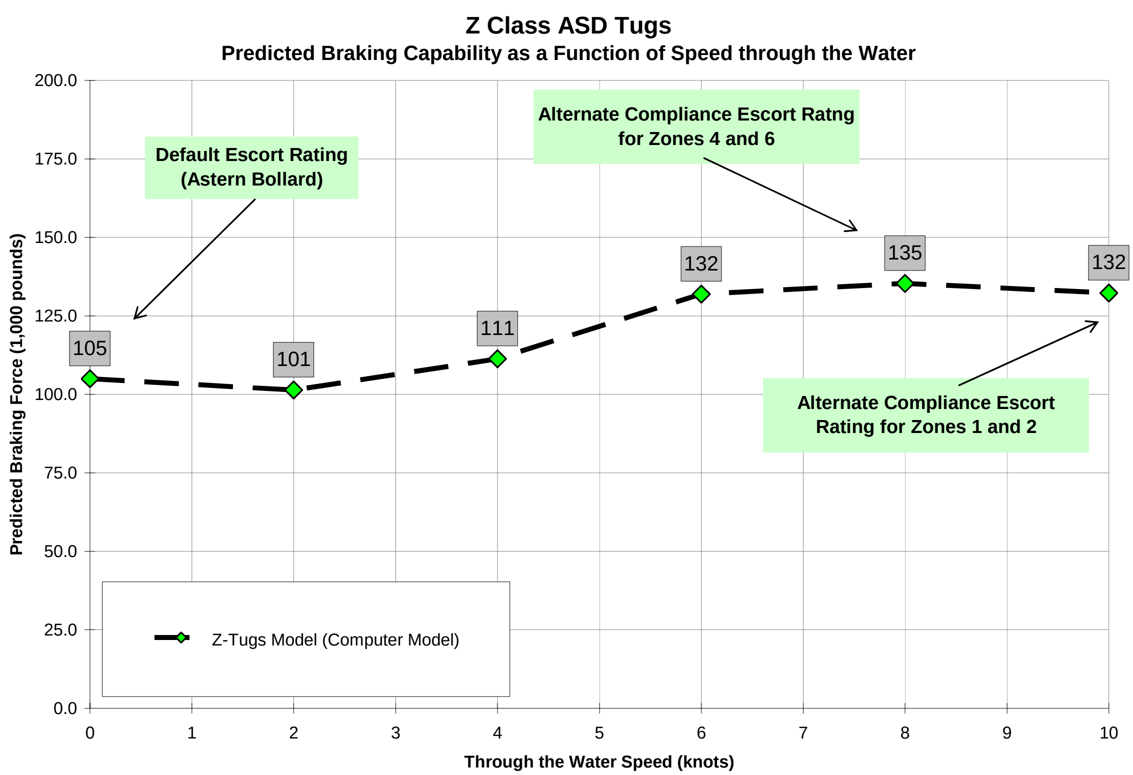


Fig. 2 Predicted Braking Forces

Table 3: Default Matrix Option for Matching Tugs to Tankers and the Result of Matching the Millennium 105' Tractor Tugs based on their Braking Force at Speed from Table 1

	Zones 1 and 2 Initial STW 10 knots			Zones 4 and 6 Initial STW 8 knots		
Assisting Current	slack	2 knot	4 knot	slack	2 knot	4 knot
Displacement (long tons)	**Braking Force in kips (1,000 pounds of force)**					
20,000	20	30	40	40	70	110
30,000	20	40	60	50	90	160
40,000	30	50	70	60	120†	210
50,000	30	60	90	70	150	250
60,000	40	70	110	100	190	320
80,000	50	90	140	120†	250	420
100,000	60	110	180	150	300	520
120,000	70	130	210	180	370	650
140,000	80	150	240	210	430	760
160,000	90	190	310	240	490	860
180,000	100	210	350	260	550	970
200,000	110	230	390	**	**	**
220,000	120†	250	420	**	**	**

** Vessels with displacement more than 180,000 LT will draw more than 35 feet and therefore would not be allowed into zones 4 and 6.

† The average Millennium 105'-Class tug meets the default requirement for this size tanker, however the *Millennium Falcon* does not.

Shaded cells indicate that the average Millennium 105'-Class tugs do not meet the demand specified in the default matrix option using the astern bollard pull of the tug.

BOXED cells indicate additional tankers that may be escorted with the alternate compliance rating based on tug forces at speed from Table 2,. i.e. when using the alternate compliance numbers from Table 2, the capabilities of the tug at that speed are greater than the required forces.

Table 4: Default Matrix Option for Matching Tugs to Tankers and the Result of Matching the Z-Class Tractor Tugs based on their Braking Force at Speed from Table 1

	Zones 1 and 2 **Initial STW 10 knots**			Zones 4 and 6 **Initial STW 8 knots**		
Assisting Current	slack	2 knot	4 knot	slack	2 knot	4 knot
Displacement (long tons)	**Braking Force in kips (1,000 pounds of force)**					
20,000	20	30	40	40	70	110
30,000	20	40	60	50	90	160
40,000	30	50	70	60	120	210
50,000	30	60	90	70	150	250
60,000	40	70	110	100	190	320
80,000	50	90	140	120	250	420
100,000	60	110	180	150	300	520
120,000	70	130	210	180	370	650
140,000	80	150	240	210	430	760
160,000	90	190	310	240	490	860
180,000	100	210	350	260	550	970
200,000	110	230	390	**	**	**
220,000	120	250	420	**	**	**

** Vessels with displacement more than 180,000 LT will draw more than 35 feet and therefore would not be allowed into zones 4 and 6.

Shaded cells indicate that the average Z-Class tug does not meet the demand specified in the default matrix option using the astern bollard pull of the tug.

BOXED cells indicate additional tankers that may be escorted with the alternate compliance rating based on tug forces at speed from Table 2,. i.e. when using the alternate compliance numbers from Table 2, the capabilities of the tug at that speed are greater than the required forces.

Table 5: Stopping Distance from 10 and 8 knots with the Millennium 105'-Class Tractor Tugs based on their Braking Force at Speed from Table 2

(2 minute Time Delay)

	Zones 1 and 2 **Initial STW 10 knots**			Zones 4 and 6 **Initial STW 8 knots**		
Assisting Current	slack	2 knot	4 knot	slack	2 knot	4 knot
Displacement (long tons)	**Stopping Distance (feet) – Millennium 105'-Class Tugs**					
20,000	2,590	3,390	4,280	2,060	2,830	3,700
30,000	2,990	4,000	5,130	2,360	3,320	4,420
40,000	3,380	4,590	5,970	2,650	3,790	5,130
50,000	3,770	5,170	6,790	2,940	4,260	5,830
60,000	4,140	5,730	7,600	3,220	4,730	6,520
80,000	4,870	6,850	9,180	3,770	5,640	7,890
100,000	5,570	7,920	10,730	4,310	6,530	9,240
120,000	6,250	8,970	12,240	4,840	7,400	10,560
140,000	6,910	9,990	13,720	5,350	8,260	11,860
160,000	7,550	10,990	15,170	5,850	9,100	13,140
180,000	8,180	11,970	16,590	6,340	9,930	14,410
200,000	8,790	12,930	17,990	**	**	**
220,000	9,380	13,870	19,370	**	**	**

** Vessels with displacement more than 180,000 LT will draw more than 35 feet and therefore would not be allowed into zones 4 and 6.

Yellow shaded cells indicate that the Millennium 105'-Class Tractor Tugs do not meet the demand specified in the default matrix option using the astern bollard pull of the tug.

BOXED cells indicate additional tankers that may be escorted with the alternate compliance rating based on tug forces at speed from Table 2,. i.e. when using the alternate compliance numbers from Table 2, the capabilities of the tug at that speed are greater than the required forces.

Table 6: Stopping Distance from 10 and 8 knots with the Z-Class Tractor Tugs based on their Braking Force at Speed from Table 1

(2 minute Time Delay)

	Zones 1 and 2 **Initial STW 10 knots**			Zones 4 and 6 **Initial STW 8 knots**		
Assisting Current	slack	2 knot	4 knot	slack	2 knot	4 knot
Displacement (long tons)	**Stopping Distance (feet) – Z-Class Tractor Tugs**					
20,000	2,840	3,780	4,840	2,180	3,040	4,010
30,000	3,360	4,570	5,960	2,540	3,630	4,890
40,000	3,860	5,330	7,050	2,890	4,200	5,750
50,000	4,350	6,080	8,120	3,240	4,770	6,600
60,000	4,820	6,810	9,180	3,570	5,320	7,430
80,000	5,740	8,230	11,220	4,230	6,410	9,080
100,000	6,620	9,600	13,200	4,860	7,470	10,690
120,000	7,460	10,920	15,130	5,480	8,510	12,280
140,000	8,270	12,200	17,010	6,080	9,520	13,830
160,000	9,060	13,440	18,840	6,660	10,510	15,350
180,000	9,820	14,660	20,640	7,230	11,490	16,860
200,000	10,560	15,840	22,400	**	**	**
220,000	11,270	17,000	24,130	**	**	**

** Vessels with displacement more than 180,000 LT will draw more than 35 feet and therefore would not be allowed into zones 4 and 6.

Shaded cells indicate that the average Z-Class tug does not meet the demand specified in the default matrix option using the astern bollard pull of the tug.

BOXED cells indicate additional tankers that may be escorted with the alternate compliance rating based on tug forces at speed from Table 2,. i.e. when using the alternate compliance numbers from Table 2, the capabilities of the tug at that speed are greater than the required forces.

Table 7: Coasting Distance from 10 and 8 knots down to 5 knots
(no tug)

	Zones 1 and 2 **Initial STW 10 knots**			Zones 4 and 6 **Initial STW 8 knots**		
Assisting Current	slack	2 knot	4 knot	slack	2 knot	4 knot
Displacement (long tons)	**Stopping distance (feet) – no tug**					
20,000	7,540	9,710	11,890	5,110	6,740	8,370
30,000	8,630	11,120	13,610	5,850	7,720	9,580
40,000	9,500	12,240	14,980	6,440	8,490	10,550
50,000	10,230	13,180	16,140	6,930	9,150	11,360
60,000	10,870	14,010	17,150	7,370	9,720	12,080
80,000	11,970	15,420	18,870	8,110	10,700	13,290
100,000	12,890	16,610	20,330	8,740	11,530	14,320
120,000	13,700	17,650	21,600	9,290	12,250	15,220
140,000	14,420	18,580	22,740	9,780	12,900	16,020
160,000	15,080	19,430	23,780	10,220	13,480	16,750
180,000	15,680	20,210	24,730	10,630	14,030	17,420
200,000	16,240	20,930	25,620	**	**	**
220,000	16,770	21,600	26,440	**	**	**

** Vessels with displacement more than 180,000 LT will draw more than 35 feet and therefore would not be allowed into zones 4 and 6.

Table 8: Stopping Distance from 5 knots with the 'Minimum Compliance Tug'

	Zones 1 and 2			Zones 4 and 6		
Assisting Current	slack	2 knot	4 knot	slack	2 knot	4 knot
Displacement (long tons)	**Stopping distance (feet)-** 'Minimum Compliance Tug'					
20,000	2,210	3,190	4,150	1,320	1,630	1,840
30,000	3,070	3,560	4,180	1,530	1,850	1,890
40,000	2,860	3,790	4,720	1,680	1,860	1,920
50,000	3,440	3,950	4,620	1,790	1,870	2,000
60,000	3,210	4,060	4,560	1,570	1,800	1,910
80,000	3,430	4,230	4,780	1,720	1,820	1,930
100,000	3,590	4,340	4,680	1,730	1,890	1,950
120,000	3,710	4,420	4,810	1,740	1,850	1,890
140,000	3,800	4,480	4,900	1,750	1,860	1,890
160,000	3,880	4,110	4,410	1,750	1,870	1,910
180,000	3,940	4,190	4,410	1,810	1,870	1,910
200,000	3,990	4,250	4,400	**	**	**
220,000	4,040	4,300	4,490	**	**	**

** Vessels with displacement more than 180,000 LT will draw more than 35 feet and therefore would not be allowed into zones 4 and 6.

Table 9: Sum of Coasting Distance to 5 knots and Stopping Distance from 5 knots with the 'Minimum Compliance Tug' (Sum of Tables 7 and 8)

	Zones 1 and 2 **Initial STW 10 knots**			Zones 4 and 6 **Initial STW 8 knots**		
Assisting Current	slack	2 knot	4 knot	slack	2 knot	4 knot
Displacement (long tons)	**Stopping distance (feet)** 'Minimum Compliance Tug'					
20,000	9,750	12,900	16,040	6,430	8,380	10,220
30,000	11,700	14,680	17,800	7,390	9,570	11,480
40,000	12,360	16,030	19,700	8,120	10,360	12,470
50,000	13,670	17,130	20,760	8,730	11,020	13,370
60,000	14,090	18,080	21,720	8,940	11,520	13,990
80,000	15,400	19,650	23,650	9,840	12,530	15,230
100,000	16,480	20,950	25,010	10,470	13,420	16,270
120,000	17,410	22,070	26,420	11,030	14,110	17,110
140,000	18,220	23,060	27,650	11,530	14,760	17,920
160,000	18,960	23,540	28,200	11,980	15,360	18,660
180,000	19,620	24,400	29,140	12,450	15,900	19,330
200,000	20, 240	25,180	30,020	**	**	**
220,000	20,810	25,910	30,940	**	**	**

** Vessels with displacement more than 180,000 LT will draw more than 35 feet and therefore would not be allowed into zones 4 and 6.

Table 10: Ratio of Stopping Distance with the 'Minimum Compliance Tug' to Stopping Distance with the Millennium 105'-Class Tractor Tugs based on their Braking Force at Speed from Table 2
(Ratio of Tables 6 and 3)

	Zones 1 and 2 **Initial STW 10 knots**			Zones 4 and 6 **Initial STW 8 knots**		
Assisting Current	slack	2 knot	4 knot	slack	2 knot	4 knot
Displacement (long tons)	Stopping distance 'minimum compliance tug' divided by Stopping distance Millennium 105'-Class Tugs					
20,000	3.8	3.8	3.7	3.1	3.0	2.8
30,000	3.9	3.7	3.5	3.1	2.9	2.6
40,000	3.7	3.5	3.3	3.1	2.7	
50,000	3.6	3.3	3.1	3.0	2.6	
60,000	3.4	3.2	2.9	2.8		
80,000	3.2	2.9	2.6	2.6		
100,000	3.0	2.6	2.3	2.4		
120,000	2.8	2.5				
140,000	2.6	2.3				
160,000	2.5					
180,000	2.4					
200,000	2.3					
220,000	2.2					

Yellow shaded cells indicate that the Millennium 105'-Class Tractor Tugs do not meet the demand specified in the default matrix option using the astern bollard pull of the tug.

BOXED cells indicate additional tankers that may be escorted with the alternate compliance rating based on tug forces at speed from Table 2,. i.e. when using the alternate compliance numbers from Table 2, the capabilities of the tug at that speed are greater than the required forces.

Table 11: Ratio of Stopping Distance with the 'Minimum Compliance Tug' to Stopping Distance with the Z-Class Tractor Tugs based on their Braking Force at Speed from Table 2 (Ratio of Tables 6 and 3)

	Zones 1 and 2 **Initial STW 10 knots**			Zones 4 and 6 **Initial STW 8 knots**		
Assisting Current	slack	2 knot	4 knot	slack	2 knot	4 knot
Displacement (long tons)	Stopping distance 'minimum compliance tug' divided by Stopping distance Z-Class Tugs					
20,000	3.4	3.4	3.3	2.9	2.8	2.5
30,000	3.5	3.2	3.0	2.9	2.6	
40,000	3.2	3.0	2.8	2.8	2.5	
50,000	3.1	2.8	2.6	2.7		
60,000	2.9	2.7	2.4	2.5		
80,000	2.7	2.4		2.3		
100,000	2.5	2.2				
120,000	2.3	2.0				
140,000	2.2					
160,000	2.1					
180,000	2.0					
200,000	1.9					
220,000	1.8					

Shaded cells indicate that the average Z-Class tug does not meet the demand specified in the default matrix option using the astern bollard pull of the tug.

BOXED cells indicate additional tankers that may be escorted with the alternate compliance rating based on tug forces at speed from Table 2,. i.e. when using the alternate compliance numbers from Table 2, the capabilities of the tug at that speed are greater than the required forces.