International Council on Clean Transportation
Working Paper #5

Inertia Classes Proposal

WLTP-DTP-LabProcICE-077
Submission to the UNECE GRPE informal subgroup on the development of a worldwide harmonized light vehicles test procedure (WLTP-DTP)

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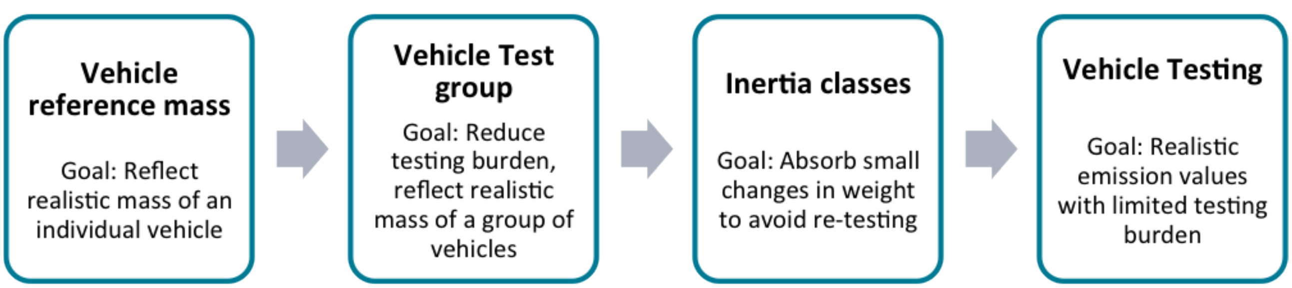
INTRODUCTION

Historically the weight of a vehicle was represented by hanging rotating inertia mass on a dynamometer. This approach required the use of discrete inertia classes and an upper limit for inertia mass. Modern electronic dynamometers do not impose these limitations anymore. As a result it is now possible to revise existing test procedures and provide more accurate emission / fuel consumption values to consumers. This document builds on more detailed explanations that were given in the documents WLTP-DTP-LabProcICE-054 and WLTP-DTP-LabProcICE-067, and presents, for discussion, a proposal for defining inertia classes for the WLTP GTR.

GENERAL

The definition of inertia classes is closely linked to the definition of vehicle reference mass and vehicle test groups.



REFERENCE MASS

Reference mass (also called test weight basis, loaded vehicle weight or vehicle test mass) can vary for two vehicles with the same technical parameters but differences in the optional equipment. Whereas Japan and the US take into account optional equipment when determining the reference mass of a vehicle, this is currently not the case in Europe and India. Furthermore, there are differences in the definition of reference mass across these countries / regions that arise due to differences in including fuels, tools, etc. See Table 1 for a summary of current reference mass definitions across the world.

Table 1: Comparison of reference mass definitions around the world

	Empty (dry) vehicle	Fluids	Fuel	Tool kit	Spare wheel	Driver & luggage	Optional equipment
US	yes	yes	yes	yes	yes	136 kg	if more than 33%*
JP	yes	yes	yes	no	no	110 kg	full
EU	yes	yes	90%	yes	yes	100 kg	no
IN	yes	yes	90%	yes	yes	150 kg	no
CN	yes	yes	90%	yes	yes	100 kg	no

Source: Based on WLTP-02-09 with additions from ICCT

* “Where it is expected that more than 33 percent of a car line, within a test group, will be equipped with an item (whether that item is standard equipment or an option), the full estimated weight of that item must be included in the curb weight computation for each vehicle available with that item in that car line, within that test group.” 40 CFR Ch. I §86.1832-01

Generally it is desirable to aim for a definition of reference mass that reflects the weight of a vehicle as closely as possible, taking into account various options in terms of configuration that customers in reality can choose from. It has been argued that in particular the EU definition (and the Indian / Chinese definitions that are based on the EU definition) of reference mass does not reflect the actual mass of a vehicle under real world operating conditions. In WLTP-DTP-LabProcICE-069 it is proposed to define the reference mass based on the unladen mass of a vehicle plus x% of the difference between the technically permissible laden mass (gross vehicle weight) and the unladen mass. Other proposals include adding the mass of y% of the optional equipment to the unladen mass to arrive at reference mass (similar to the current US approach) or introducing an emission correction factor for taking into account extra weight due to the optional equipment.

The definition of reference mass is not part of this proposal. The term “reference mass” in the following is used as a placeholder for the definition of reference mass that is agreed to within the WLTP process.

VEHICLE TEST GROUP

Grouping vehicles of similar characteristics that are likely to have very similar emission levels can help to reduce the testing burden of manufacturers. For fuel economy testing in the US, vehicles are grouped using inertia weight classes (IWC). Vehicles that share the same basic engine, engine code, IWC, transmission configuration, and axle ratio are considered to have the same vehicle configuration. Out of the vehicles that have the same vehicle configuration for fuel economy purposes only the vehicle with the highest projected sales could be tested.[1] Other configurations may be tested at the manufacturer's option. It is important to note that the IWC are different from the inertia classes discussed in the following section of this document.[2]

A similar approach could be chosen for the WLTP in order to limit the amount of testing burden for manufacturers. However, the definition of vehicle test groups is not part of this proposal and would need to be addressed elsewhere in the WLTP process.

INERTIA CLASSES

As explained in documents WLTP-DTP-LabProcICE-054 and WLTP-DTP LabProcICE-067 there is no longer a technical need to use discrete inertia weight classes for vehicle emission / fuel consumption testing. Instead, it would be desirable to apply a step-less approach that makes use of the actual reference mass of a vehicle. Yet, for practical reasons it might be beneficial to have some buffer to ensure that not every small change in vehicle mass results in a need to re-test the vehicle. Hence, for the near future it could be argued to stick to the concept of inertia classes not for technical but for practical reasons until a better concept is described.

When deciding about the size of the inertia class steps there is a trade-off to consider: inertia classes should avoid creating incentives for manufacturers to increase or decrease the weight of a vehicle for the sole purpose of achieving a more favourable test weight. Additionally, inertia classes should avoid a situation where increases or decreases in vehicle weight are not adequately reflected in new test weights. These objectives clearly speak in favour of having small inertia classes. On the other hand, larger inertia classes are more likely to reduce the testing burden for manufacturers, as the changes in weight need to be larger before a re-testing of a vehicle becomes necessary.

During earlier discussions it was suggested that inertia class steps should reflect CO_2 emission changes of approximately 1 g/km in order to be meaningful. In WLTP-DTP-LabProcICE-065 an estimate was provided for the effects of 100 kg of weight variation in the EU NEDC test cycle under the assumption that no secondary weight and fuel saving effects[3] are taken into account. In the underlying paper (see footnote 4) more details are given and the effects for the US and Japanese test cycles can be calculated. As both cycles tend to be more dynamic than the EU NEDC, the acceleration energy needed and therefore the effects of changes in weight are higher for

1 "The test weight for a fuel economy data vehicle will be that test weight specified by the Administrator from the test weights covered by that vehicle configuration. The Administrator will base his selection of a test weight on the relative projected sales volumes of the various test weights within the vehicle configuration." 40 CFR § 600.111-80

2 IWC in the US are between 250 lbs (113 kg) and 500 lbs (227 kg) and therefore higher than the current inertia classes (called equivalent test weight – ETW).

3 Secondary fuel saving effects: Fuel savings due to changes in gear ratio and engine displacement to achieve equal performance after weight reduction; Secondary weight savings: Fuel savings due to downsizing of engines, smaller breaks etc. after weight reduction.

the Combined (US) and 10-15 (JP) cycles than they are for the NEDC (EU). Furthermore, the paper states that "the larger the weight reduction, the more probable an adjustment of the gear ratio or the engine displacement becomes" and "In practice, both FRV [fuel reduction values with and without secondary weight effects] are equally likely in case that no comprehensive information is available about whether a weight-inducted power train adaptation will take place or not." Hence, the respective information for changes in CO_2 when considering secondary weight effects has been added in table 2. The table furthermore lists two meta-studies from the US EPA/NTHSA and FKA.

Table 2: Summary CO_2 effects of 100 kg of weight variation

Source	Secondary effects	Test cycle	CO_2 effect of 100 kg of weight/ variation (g/km)[4]			Weight variation reflecting 1 g/km of CO_2 (kg)
			Min.	Max.	Arith. mean	
VW[5]	no	NEDC (EU)	3.2	3.5	3.3	30
	no	Combined (US)	3.5	3.8	3.6	27
	no	10-15 (JP)	4.1	4.4	4.3	23
	yes	NEDC (EU)	6.3	10.6	8.5	12
EPA[6]	no	Combined (US)	3.8	3.8	3.8	27
	yes	Combined (US)	7.0	7.0	7.0	14
FKA[7]	no	NEDC (EU)	2.0	6.2	4.1	24
	yes	NEDC (EU)	5.5	8.8	7.1	14

Assessing the actual CO_2 effect of inertia classes obviously depends on the individual vehicle, the technological changes applied and the test cycle. Yet, even if assuming a worst-case scenario with no secondary fuel and weight saving effects being taken into account and assuming that the new DHC will be as static as the current EU NEDC (which is unlikely) it becomes clear from Table 2 that an inertia class size of maximum 30 kg will result in a CO_2 effect of approximately 1 g/km.

4 For conversion from (l/100 km) fuel consumption into (g/km) CO_2 emissions EUCAR / CONCAWE / JRC conversion factors are applied (see Well-to-Wheels analysis of future automotive fuels and powertrains in the European context); for calculating CO_2 effects a 1,400 kg and 150 g/km CO_2 passenger car is assumed.

5 Koffler, C., Rohde-Brandenburger, K. On the calculation of fuel savings through lightweight design in automotive life cycle assessments. International Journal of Life Cycle Assessment (2010) 15:128-135. Calculations for US and JP test cycles based on factors given in the paper under the assumption that the percentage of deceleration phases in the US and JP test cycle are the same as for the NEDC cycle (15%).

6 EPA/NHTSA. Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards – Joint Technical Support Document, 2010.

7 Forschungsgesellschaft Kraftfahrwesen mbH Aachen – FKA. Determination of weight elasticity of fuel economy for conventional ICE vehicles, hybrid vehicles and fuel cell vehicles. Report 55510, 2007.

For practical reasons, instead of choosing an inertia class size of 30 kg, it would be beneficial to set the step size at 28.35 kg (=62.50 pounds). This is exactly half the size of the steps under the current US system. The new inertia classes would therefore be compatible with the US IWC classes that would not have to be changed.

As demonstrated above, setting the size of inertia classes at 28.35 kg allows for a reasonable compromise between a) providing accurate emission and fuel consumption values that avoid incentives to increase or decrease the weight of a vehicle solely to achieve a more favourable test weight and b) limiting the testing burden as much as possible.

In addition to setting the size of the inertia class steps it is also important to include all light-duty vehicles on the market and impose equitable requirements on all of them. Therefore, the currently existing upper limit for inertia mass under the EU NEDC regulation at 2,270 kg, that used to be based on technical restrictions (see WLTP-DTP-LabProcICE-054 for an explanation), needs to be replaced by an inertia class system that includes all light-duty vehicles as defined in the WLTP.

PROPOSAL

Based on the above considerations, the following proposed text on inertia class definition is provided for discussion.

For the purpose of the determination of emissions and fuel consumption, the inertia weight used to adjust the dynamometer will be chosen as follows:

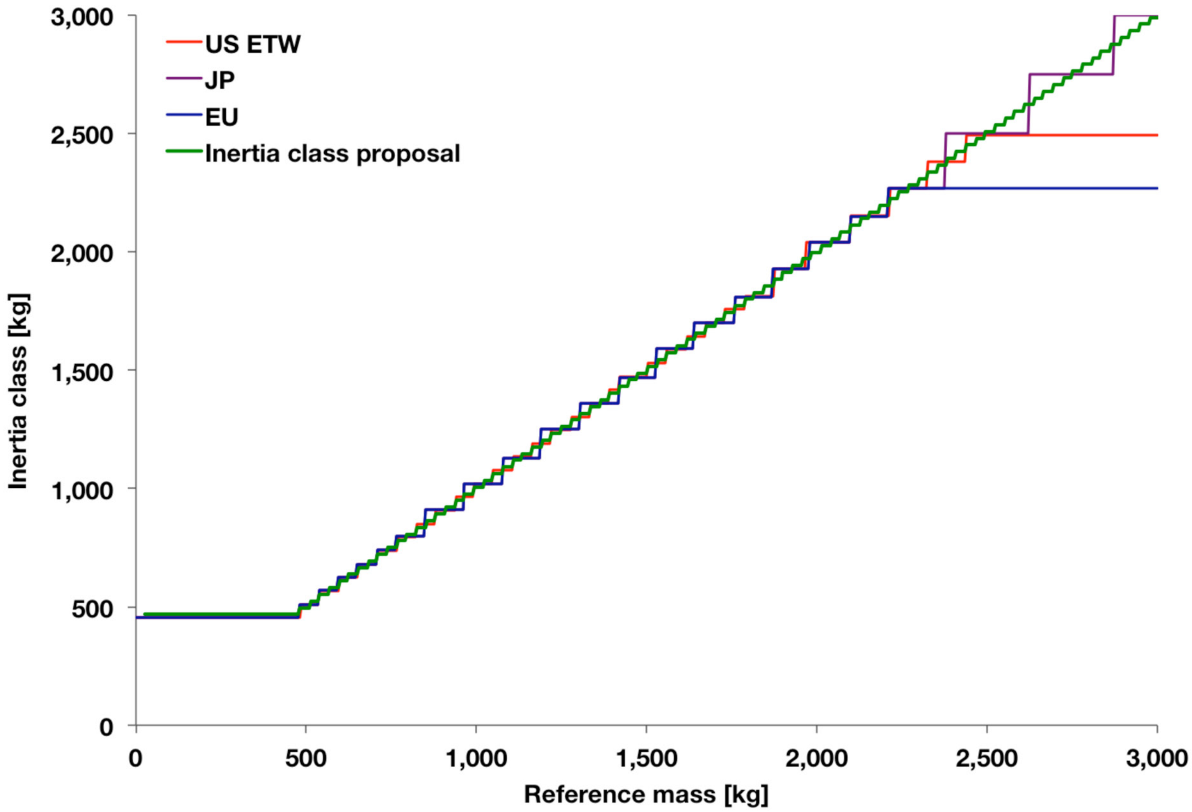
Reference mass of vehicle RW (kg)					Inertia class IC (kg)
		RW	≤	481	468
482	<	RW	≤	510	496
510	<	RW	≤	538	524
539	<	RW	≤	567	553
567	<	RW	≤	595	581
595	<	RW	≤	623	609
624	<	RW	≤	652	638
652	<	RW	≤	680	666
680	<	RW	≤	708	694
Continue in increments of 28.35 kg					

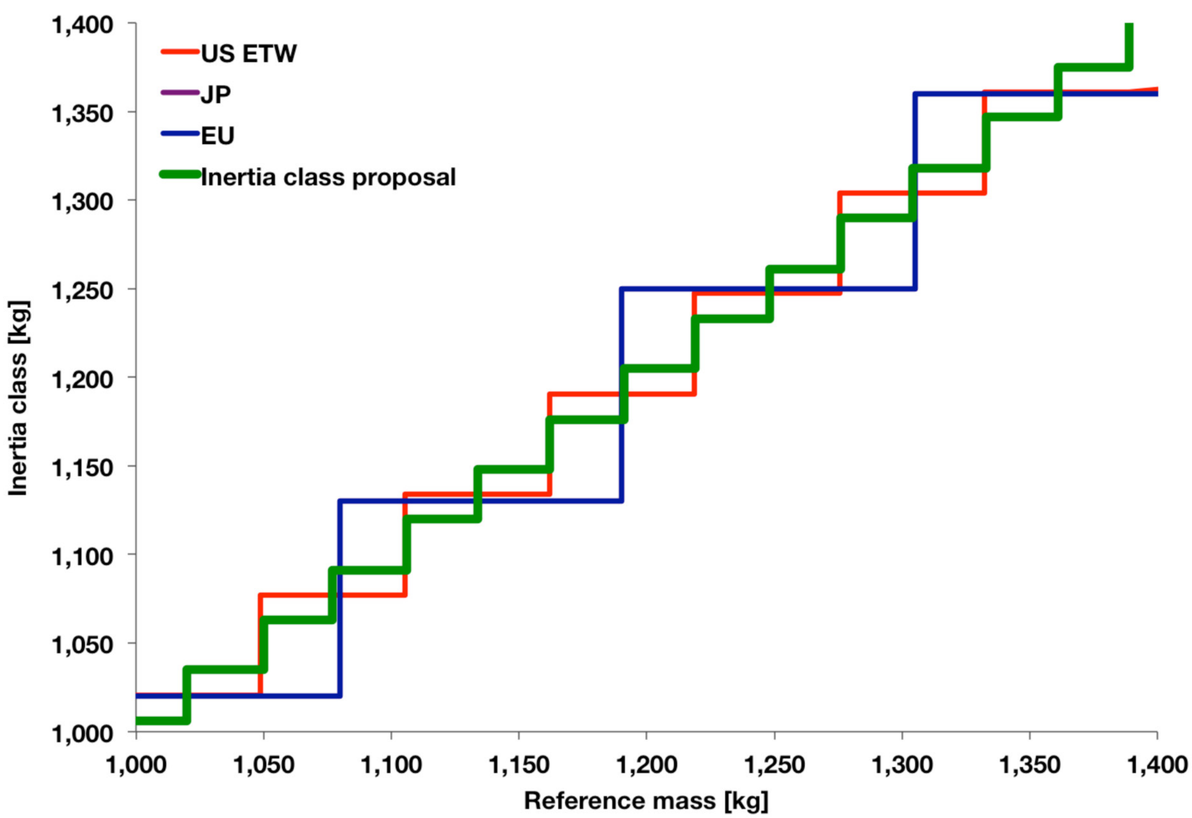
(note that the term reference mass is used here as a placeholder for the vehicle test mass defined in the WLTP)

Annex 1- Comparision with US inertia weight classes

Reference mass, RW										Inertia class, IC		Inertia weight class, IWC	
(pounds)					(kilogram)					(pounds)	(kilogram)	(pounds)	(kilogram)
		RW	≤	1,062			RW	≤	481	1,031	468	1,000	454
1,063	<	RW	≤	1,124	482	<	RW	≤	510	1,093	496	1,000	454
1,125	<	RW	≤	1,187	510	<	RW	≤	538	1,156	524	1,000	454
1,188	<	RW	≤	1,249	539	<	RW	≤	567	1,218	553	1,250	567
1,250	<	RW	≤	1,312	567	<	RW	≤	595	1,281	581	1,250	567
1,313	<	RW	≤	1,374	595	<	RW	≤	623	1,343	609	1,250	567
1,375	<	RW	≤	1,437	624	<	RW	≤	652	1,406	638	1,250	567
1,438	<	RW	≤	1,499	652	<	RW	≤	680	1,468	666	1,500	680
1,500	<	RW	≤	1,562	680	<	RW	≤	708	1,531	694	1,500	680
1,563	<	RW	≤	1,624	709	<	RW	≤	737	1,593	723	1,500	680
1,625	<	RW	≤	1,687	737	<	RW	≤	765	1,656	751	1,500	680
1,688	<	RW	≤	1,749	765	<	RW	≤	793	1,718	779	1,750	794
1,750	<	RW	≤	1,812	794	<	RW	≤	822	1,781	808	1,750	794
1,813	<	RW	≤	1,874	822	<	RW	≤	850	1,843	836	1,750	794
1,875	<	RW	≤	1,937	851	<	RW	≤	878	1,906	864	1,750	794
1,938	<	RW	≤	1,999	879	<	RW	≤	907	1,968	893	2,000	907
2,000	<	RW	≤	2,062	907	<	RW	≤	935	2,031	921	2,000	907
2,063	<	RW	≤	2,124	936	<	RW	≤	964	2,093	950	2,000	907
2,125	<	RW	≤	2,187	964	<	RW	≤	992	2,156	978	2,000	907
2,188	<	RW	≤	2,249	992	<	RW	≤	1020	2,218	1,006	2,250	1,021
2,250	<	RW	≤	2,312	1021	<	RW	≤	1049	2,281	1,035	2,250	1,021
2,313	<	RW	≤	2,374	1049	<	RW	≤	1077	2,343	1,063	2,250	1,021
2,375	<	RW	≤	2,437	1077	<	RW	≤	1105	2,406	1,091	2,250	1,021
2,438	<	RW	≤	2,499	1106	<	RW	≤	1134	2,468	1,120	2,500	1,134
2,500	<	RW	≤	2,562	1134	<	RW	≤	1162	2,531	1,148	2,500	1,134
2,563	<	RW	≤	2,624	1162	<	RW	≤	1190	2,594	1,176	2,500	1,134
2,625	<	RW	≤	2,687	1191	<	RW	≤	1219	2,656	1,205	2,500	1,134
2,688	<	RW	≤	2,749	1219	<	RW	≤	1247	2,719	1,233	2,750	1,247
2,750	<	RW	≤	2,812	1248	<	RW	≤	1275	2,781	1,261	2,750	1,247
2,813	<	RW	≤	2,874	1276	<	RW	≤	1304	2,844	1,290	2,750	1,247
2,875	<	RW	≤	2,937	1304	<	RW	≤	1332	2,906	1,318	2,750	1,247
2,938	<	RW	≤	2,999	1333	<	RW	≤	1360	2,969	1,347	3,000	1,361
3,000	<	RW	≤	3,062	1361	<	RW	≤	1389	3,031	1,375	3,000	1,361
3,063	<	RW	≤	3,124	1389	<	RW	≤	1417	3,094	1,403	3,000	1,361
3,125	<	RW	≤	3,187	1418	<	RW	≤	1446	3,156	1,432	3,000	1,361
3,188	<	RW	≤	3,249	1446	<	RW	≤	1474	3,219	1,460	3,000	1,361
3,250	<	RW	≤	3,312	1474	<	RW	≤	1502	3,281	1,488	3,000	1,361
3,313	<	RW	≤	3,374	1503	<	RW	≤	1531	3,344	1,517	3,500	1,588
3,375	<	RW	≤	3,437	1531	<	RW	≤	1559	3,406	1,545	3,500	1,588
3,438	<	RW	≤	3,499	1559	<	RW	≤	1587	3,469	1,573	3,500	1,588
3,500	<	RW	≤	3,562	1588	<	RW	≤	1616	3,531	1,602	3,500	1,588
3,563	<	RW	≤	3,624	1616	<	RW	≤	1644	3,594	1,630	3,500	1,588
3,625	<	RW	≤	3,687	1644	<	RW	≤	1672	3,656	1,658	3,500	1,588
3,688	<	RW	≤	3,749	1673	<	RW	≤	1701	3,719	1,687	3,500	1,588
3,750	<	RW	≤	3,812	1701	<	RW	≤	1729	3,781	1,715	3,500	1,588
3,813	<	RW	≤	3,874	1730	<	RW	≤	1757	3,844	1,743	4,000	1,814
3,875	<	RW	≤	3,937	1758	<	RW	≤	1786	3,906	1,772	4,000	1,814
3,938	<	RW	≤	3,999	1786	<	RW	≤	1814	3,969	1,800	4,000	1,814
4,000	<	RW	≤	4,062	1815	<	RW	≤	1842	4,031	1,829	4,000	1,814
4,063	<	RW	≤	4,125	1843	<	RW	≤	1871	4,094	1,857	4,000	1,814
4,126	<	RW	≤	4,187	1871	<	RW	≤	1899	4,156	1,885	4,000	1,814
4,188	<	RW	≤	4,250	1900	<	RW	≤	1928	4,219	1,914	4,000	1,814
4,251	<	RW	≤	4,312	1928	<	RW	≤	1956	4,281	1,942	4,000	1,814
4,313	<	RW	≤	4,375	1956	<	RW	≤	1984	4,344	1,970	4,000	1,814
4,376	<	RW	≤	4,437	1985	<	RW	≤	2013	4,406	1,999	4,500	2,041
4,438	<	RW	≤	4,500	2013	<	RW	≤	2041	4,469	2,027	4,500	2,041
4,501	<	RW	≤	4,562	2041	<	RW	≤	2069	4,531	2,055	4,500	2,041
4,563	<	RW	≤	4,625	2070	<	RW	≤	2098	4,594	2,084	4,500	2,041
4,626	<	RW	≤	4,687	2098	<	RW	≤	2126	4,656	2,112	4,500	2,041
4,688	<	RW	≤	4,750	2126	<	RW	≤	2154	4,719	2,140	4,500	2,041
4,751	<	RW	≤	4,812	2155	<	RW	≤	2183	4,781	2,169	4,500	2,041
4,813	<	RW	≤	4,875	2183	<	RW	≤	2211	4,844	2,197	4,500	2,041
4,876	<	RW	≤	4,937	2212	<	RW	≤	2239	4,906	2,225	5,000	2,268
4,938	<	RW	≤	5,000	2240	<	RW	≤	2268	4,969	2,254	5,000	2,268
5,001	<	RW	≤	5,062	2268	<	RW	≤	2296	5,031	2,282	5,000	2,268
5,063	<	RW	≤	5,125	2297	<	RW	≤	2325	5,094	2,311	5,000	2,268
5,126	<	RW	≤	5,187	2325	<	RW	≤	2353	5,156	2,339	5,000	2,268
5,188	<	RW	≤	5,250	2353	<	RW	≤	2381	5,219	2,367	5,000	2,268
5,251	<	RW	≤	5,312	2382	<	RW	≤	2410	5,281	2,396	5,000	2,268
5,313	<	RW	≤	5,375	2410	<	RW	≤	2438	5,344	2,424	5,000	2,268
5,376	<	RW	≤	5,437	2438	<	RW	≤	2466	5,406	2,452	5,500	2,495
5,438	<	RW	≤	5,500	2467	<	RW	≤	2495	5,469	2,481	5,500	2,495
5,501	<	RW	≤	5,562	2495	<	RW	≤	2523	5,531	2,509	5,500	2,495
5,563	<	RW	≤	5,625	2523	<	RW	≤	2551	5,594	2,537	5,500	2,495
5,626	<	RW	≤	5,687	2552	<	RW	≤	2580	5,656	2,566	5,500	2,495
5,688	<	RW	≤	5,750	2580	<	RW	≤	2608	5,719	2,594	5,500	2,495
										Continue in increments of 62.5 pounds		Continue in increments of 500 pounds	

Annex II- Comparison with existing regulation





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