ZDDPlus, LLC
Burlington, NC 27215
www.zddplus.com

ZDDPlus™ Tech Brief #7

Oil Additive Dosing and Dilution

A common problem cropping up in discussions of oil additives is the use of incorrect dosing amounts, usually due to a misunderstanding of how dilutions and resulting concentrations are calculated. In chemical formulation (unlike cooking) the quantity of a specific atom or molecule determines its characteristics when combined with other chemicals. Since the weight of a single atom or molecule is a known quantity, we measure bulk amounts of chemicals by weight. When calculating the concentration of various atomic or molecular constituents in a mixture, we are looking for that particular element or molecule's weight as a fraction or percentage of total mixture weight. If volumes are used instead of weights, measurement or dosing errors will often occur. The difference is most substances differ in density from each other; therefore similar volumes of these substances will have different weights. In order to correctly calculate weight fractions from a mixture of substances of differing densities or atomic weights, density or atomic mass of each constituent must be factored into the calculation.

In the case of determining relative amounts of chemicals such as the phosphorus in an oil additive, we must factor the relative density of the additive separately to that of the oil. Various grades of motor oil have a density of between .82 and .88 grams per cm^3, depending on viscosity and additive package. 0.86 grams per cm^3 is an average value we use when calculating oil additive dilutions that we arrived at after measuring many different 10W-30 motor oils. For the density of ZDDPlus™ we use the average value of 0.99 grams per cm^3. For the density of EOS we measured 0.91 grams per cm^3. Once density has been factored in, we can use straight volumes for dilutions.

Directly measuring the amount of ZDDP in an additive is extremely difficult due to the mixture of different alcohols used in its manufacture, and the resulting range of atomic weights of the ZDDP molecules. The most common way to indirectly measure the ZDDP content is to use one of several ASTM test methods to measure the phosphorus and zinc content. Zinc can often be added to oils as an acid neutralizing agent, so zinc is not a reliable indicator of ZDDP. Since phosphorus is found in oils predominantly in the form of ZDDP, we use it as the measurement criteria for ZDDP. If you are using a phosphorus test result as an indicator, the correct way to state ZDDP level is to state an amount of ZDDP that results in a certain phosphorus level. Phosphorus is also the element identified as most potentially compromising to the catalytic converter, so there is a maximum 800 ppm or 0.08% phosphorus level specified in the SM oil classification. SF oil was in common use back in the time of older high-performance cars with flat tappets and higher than current valve-spring pressures. The best heavy-duty oils of that time contained a level of ZDDP which resulted in a phosphorus level measured in the range of 1200 to 1600 ppm. Recent testing of modern SM oils reveals that many contain around 600 ppm of phosphorus. Therefore, to accurately estimate the total amount of phosphorus in the final oil, we add this 600 ppm to the amounts due to the additives. Once we have figured out the phosphorus level, zinc can be calculated in the same manner if desired.

Another factor affecting the final concentration of ZDDP and the measured phosphorus in an oil mixture is the method used by the person performing the oil change. If one uses 16 oz of EOS and a particular engine's oil sump will not allow more than, say, 5 quarts without risk of foaming from crankshaft splashing, then an amount of oil equal to the volume of the EOS additive should be taken out of the new oil. If the 4 oz bottle of ZDDPlus™ is added, this is not likely to be a problem. ZDDPlus™ was designed for correct dosing when used with 4-6 quarts of oil. With these factors in mind, we calculate the final phosphorus and zinc levels as follows:

Method 1: additive volume + 5 quarts oil:

For EOS

EOS	is	16 oz + 5 qts oil (160 oz)	= 176 oz total sump fill volume, resulting in an 11:1 dilution ratio.	
EOS	P	6210 ppm @ 11:1 dilution	= 565 ppm + 600* ppm from oil	= 1165 ppm or 0.117%
EOS	Zn	6820 ppm @ 11:1 dilution	= 620 ppm + 800* ppm from oil	= 1420 ppm or 0.142%

For ZDDPlus™

ZDDPlus™	is	4 oz + 5 qts oil (160 oz)	= 164 oz total sump fill volume, resulting in a 41:1 dilution ratio.	
ZDDPlus™	P	51500 ppm @ 41:1 dilution	= 1256 ppm + 600* ppm from oil	= 1856 ppm or 0.186%
ZDDPlus™	Zn	71800 ppm @ 41:1 dilution	= 1751 ppm + 800* ppm from oil	= 2551 ppm or 0.255%

* typical value found in SM oil

Method 2: additive volume + (5 quarts oil – additive volume):

For EOS

EOS	is	16 oz + (5 qts – 16 oz) of oil	= 160 oz total sump fill volume, resulting in a 10:1 dilution ratio.	
EOS	P	6210 ppm @ 10:1	= 621 ppm + 600* ppm from oil	= 1221 ppm or 0.122%
EOS	Zn	6820 ppm @ 10:1	= 682 ppm + 800* ppm from oil	= 1482 ppm or 0.148%

For ZDDPlus™

ZDDPlus™	is	4 oz + (5 qts - 4 oz) of oil	= 160 oz total sump fill volume, resulting in a 40:1 dilution ratio.	
ZDDPlus™	P	51500 ppm @ 40:1	= 1288 ppm + 600* ppm from oil	= 1888 ppm or 0.189%
ZDDPlus™	Zn	71800 ppm @ 40:1	= 1795 ppm + 800* ppm from oil	= 2595 ppm or 0.260%

* typical value found in SM oil

Method 1 for any oil sump of capacity (x): additive volume + (x) quarts of oil:

For EOS

Calculate EOS dilution ratio using (x) quarts of oil:

EOS is 16 oz + (**x***32) oz of oil = ((**x***32) +16) oz total sump contents volume, resulting in:
(((**x***32) +16)/16) = **y**: 1 dilution ratio.

Calculate EOS phosphorus at dilution ratio using (y) from above:

EOS P 6210 ppm @ **y** : 1 = (6210/**y**) = $\mathbf{z_p}$ ppm

Calculate total phosphorus in final oil with EOS using (z_p) from above:

$\mathbf{z_p}$ ppm + 600 ppm from oil = ($\mathbf{z_p}$+600) ppm or (($\mathbf{z_p}$+600)/10,000) %

Calculate EOS zinc at dilution ratio using (y) from above:

EOS Zn 6820 ppm @ **y** : 1 = (6820/**y**) = $\mathbf{z_z}$ ppm

Calculate total zinc in final oil with EOS using (z_z) from above:

$\mathbf{z_z}$ ppm + 600 ppm from oil = ($\mathbf{z_z}$+800) ppm or (($\mathbf{z_z}$+800)/10,000) %

For ZDDPlus™

Calculate ZDDPlus™ dilution ratio using (x) quarts of oil:

ZDDPlus™ is 4 oz + (**x***32) oz of oil = ((**x***32) +4) oz total sump contents volume, resulting in:
(((**x***32) +4)/4) = **y** : 1 dilution ratio.

Calculate ZDDPlus™ phosphorus at dilution ratio using (y) from above:

ZDDPlus™ P 51500 ppm @ **y** : 1 = (51500/**y**) = $\mathbf{z_p}$ ppm

Calculate total phosphorus in final oil with ZDDPlus™ using (z_p) from above:

$\mathbf{z_p}$ ppm + 600 ppm from oil = ($\mathbf{z_p}$+600) ppm or (($\mathbf{z_p}$+600)/10,000) %

Calculate ZDDPlus™ zinc at dilution ratio using (y) from above:

ZDDPlus™ Zn 71800 ppm @ **y** : 1 = (71800/**y**) = $\boldsymbol{z_z}$ ppm

Calculate total zinc in final oil with ZDDPlus™ using (z_z) from above:

$\mathbf{z_z}$ ppm + 600 ppm from oil = ($\mathbf{z_z}$+800) ppm or (($\mathbf{z_z}$+800)/10,000) %

The preceding calculations for the 5-quart oil changes give typical results when used in many classic American V8 engines. The target 1800 to 2000 ppm range for phosphorus is designed to give the longest possible EP service with no risk of overdosing. Based on the 0.94:1 ratio of phosphorus to zinc in the ZDDP molecule itself, this range of phosphorus would give a zinc level of about 1900 to 2100 ppm. As you can see from the ZDDPlus™ calculations, the zinc level when targeting the 1800-2000 ppm phosphorus mark falls in the 2400-2500 ppm range. This extra zinc is due to good over-compounding with zinc oxide during the ZDDP manufacture. This extra zinc in the form of zinc oxide helps give a high TBN (total base number) for excellent long-term acid neutralization. If you wish to calculate your dosing using oil having different phosphorus or zinc levels than the typical 600 ppm P and 800 ppm Zn for SM oils, substitute your values in the calculations as shown in the third section of the calculations.

For convenient reference, the following values can be used if your engine has a 4-quart oil capacity:

The resulting P and Zn values will be approximately:

11% higher P for EOS:	1290 ppm for 4 quart vs. 1165 ppm for 5 quart.
10% higher Zn for EOS:	1558 ppm for 4 quart vs. 1420 ppm for 5 quart.
15% higher P for ZDDPlus™:	2134 ppm for 4 quart vs. 1856 ppm for 5 quart.
15% higher Zn for ZDDPlus™:	2933 ppm for 4 quart vs. 2551 ppm for 5 quart.

We believe dosing a 4-quart oil change with one 4 oz bottle of ZDDPlus™ is safe. If you feel you would rather have your 4-quart oil change phosphorus or zinc concentrations closer to that shown above for 5 quarts, then merely use ¾ of a single bottle (3 oz) in an oil change. If the top is replaced snugly, ZDDPlus™ will be usable in the next change, when added to ½ (2 oz) of a 4 oz bottle to equal the 3 oz dose.

For convenient reference, the following values can be used if your engine has a 6-quart oil capacity:

The resulting P and Zn values will be approximately:

8% lower P for EOS:	1078 ppm for 6 quart vs. 1165 ppm for 5 quart.
7% lower Zn for EOS:	1325 ppm for 6 quart vs. 1420 ppm for 5 quart.
12% lower P for ZDDPlus™:	1633 ppm for 6 quart vs. 1856 ppm for 5 quart.
12% lower Zn for ZDDPlus™:	2244 ppm for 6 quart vs. 2551 ppm for 5 quart.

The approximate 12% drop in P and Zn when using one 4 oz bottle of ZDDPlus™ in a 6-quart oil change is negligible, and will give EP anti-wear protection for the cam and lifters of engines with even the highest spring-pressures.

Referring to the results above using either method for a 5-quart oil fill, the addition of one 16 oz bottle of EOS would get you half way to an optimum level for a classic high-performance car, but carries with it 16 oz of oil different from the oil you add it to. However, one 4 oz bottle of ZDDPlus™ gives the proper amount with a comfortable safety margin, and you choose all but 4 oz of the oil's characteristics with your favorite oil. If you factor in normal depletion rates, then only ZDDPlus™ has the potential to maintain adequate protection for the duration of a 3000+ mile oil change.