Comparison Between *oms* Hypodrive Gear Units EC 2-7 / 15 / 25 and Worm & Worm Helical Gears Of The Same Output Power Rating

The *oms* Hypodrive gear units are two stage gear units with a helical bevel gear input stage and spur gear second (output) stage. The input stage is a highly optimized hypoid bevel gear stage of the GLEASON® type in ground quality. The output stage is an optimized helical spur gear stage, also in ground quality.
The manufacturing technology of the gear toothings are in accordance with the quality requirements of the automobile industry.
The outer dimensions of the gear units and the layout of the motor and the braking unit is similar to those used with standard worm gear units for escalator traction machines.

Picture 1: EC 2-7

Picture 2: EC 2-25

A comparison between worm gear and *oms*Hypodrive type of traction machines will be made for commercial applications, and for public applications worm and worm-helical escalator traction machines will be compared to *oms*Hypodrive units, comparing the following characteristics, based on the same output power and momentum towards the escalator.

Volume Of Gear Unit:
The volume of the *oms*Hypodrive gear unit is more than 30% smaller than a comparable worm gear or worm-helical unit of comparable output power.

Efficiency:
The efficiency of the *oms*Hypodrive gear unit (96 – 97%) is approx. 10% higher than that of a comparable good worm gear unit (84 – 87%) at full load. That means losses of 3 – 4 % for a *oms*Hypodrive gear unit, versus 13 – 16% for a worm gear unit. At loads smaller than the rated load, the *oms*Hypodrive gear units performs even better as compared to a worm gear unit. Compared to worm-helical gears with an efficiency of about 91% at maximum rated gear load, that means losses of 9% for this type of gear at full load, and more at smaller loads. Although efficiency is better than for a pure worm gear, the efficiency of *oms*Hypodrive is still way superior.
By using high efficiency class IE3 motors developed especially for escalator application on the *oms*Hypodrive traction machines, overall efficiency is boosted even more, reducing energy consumption considerably as compared to standard efficiency motors.

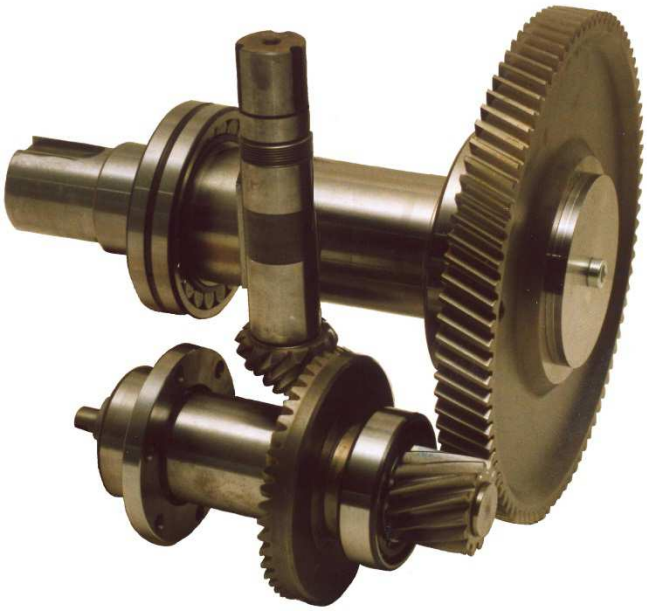
Sound Emission:
The sound power level of the *oms*Hypodrive gear units are well below the allowed sound levels as required by the major manufacturers of escalators and mowing walkways, and is comparable to well designed worm gear units. This feature is due to the optimized manufacturing technology using the most advanced GLEASON® grinding and measuring technology for the production of the gear sets.

Performance:
The *oms*Hypodrive gear units can be used continuously at their maximum output power level for indefinite time, without overheating the gear units. A worm gear unit with comparable reduction ratio may not be used continuously at it's maximum power level for more than about one hour without an additional external oil cooler or other means of reducing the temperature of the gear box. due to its high thermal losses. Also, a worm helical gear has reduced output power and momentum above $T_{AMBIENT} > 30°C$, so substantial reduction in capability for realistic operating temperatures in the escalator has to be taken into consideration.

Wear Of Toothing:
The gear toothings of the *oms*Hypodrive gears are calculated and manufactured for indefinite lifetime and are safe against tooth cracking as required by the safety margins claimed by the EN115-1:2008 standard. The hardened and ground teeth flanks show a surface smoothing after initial putting into operation, without any abrasion.

For comparison, be reminded that worm gear and worm-helical gear units can only be designed and build with a finite lifetime due to the abrasion of the bronze worm wheel, which is dependent on (equivalent) load.

Picture 3: EC 2-15
Options: Weatherproof, Short Motor, Brake Lining Wear Sensors



Picture 4: *oms* Hypodrive Input and Output Stage (Patents pending)

Oil Volumes, Oil Temperatures And Oil Changing Intervals:

The *oms* Hypodrive gear units use substantially less oil than a comparable worm gear or worm-helical gear unit. Nevertheless the operating temperatures of the *oms* Hypodrive gear units will be approx. 30K to 35K lower than for a comparable worm gear unit, and about 20K to 25K lower than for a comparable worm-helical unit with the shelf live of the oil in an *oms* Hypodrive gear unit approaching many times that of a worm gear or worm-helical unit. Due to the much lower heat generated by a *oms* Hypodrive gear unit, the thermal stress for the surrounding materials, electronic equipment, controllers etc. is considerably less when using an *oms* Hypodrive gear unit as compared to using a worm gear or worm-helical gear unit. This of course translates into much longer service intervals for the surrounding equipment, too.

For data on the oil consumption over lifetime for both commercial and public applications, the cost impact of the oil usage in terms of the amount of oil needed, and the number of oil service operations required, a detailed comparison of oil service related cost is given in the appendix.

Economical Aspects

General Maintenance:
The maintenance aspect is another aspect in favour of the *oms*Hypodrive technology. The cost benefits of the *oms*Hypodrive technology, although it is difficult to quantify according to specific regional conditions, nonetheless becomes quite evident when just comaring the cost of oil service for the hypoid machines. Therefore, the calculation of the cost advantage of the *oms*Hypodrive traction machines compared to worm gear and worm-helical gear based machines will focus only on: energy efficiency, lower oil consumption and the associated cost of oil exchange. Additional costs for the disposal of waste gear oil and other factors although also in favour of *oms*Hypodrive machines, are not being considered in this technical note.

Impact Of Gear Technology On The Application:
The *oms*Hypodrive unit needs a check of the oil via the oil level gauge initially after 10.000 and 20.000 hours, and then every 5.000 hours. This is many times the oil exchange interval for a *complete oil change for both worm gear and worm-helical drives* (6,000h). The de facto oil exchange intervals for the *oms*Hypodrive units reach 35,000 - 40.000 hours for the EC 2-25, and 20.000 – 30.000 hours for the EC 2-7, depending on the type of application, usage and environment. The change of the oil does not require the removal of the drive unit. This effectively translates into lower cost of service.

A worm gear and a worm-helical gear usually have to be replaced after approximately 70.000 h. Due to the wear of the worm wheel these escalator traction machines incorporating a worm gear stage have a life time in the field limited by the gear itself, and not only by the bearings. For commercial applications, the gears lifetime of 70,000h now translates to a usage in the application to now about 20 years, down from former useful usage of 26 years due to the higher daily usage due to largely extended opening times of shopping centres over the past years, and thus the increased number of operating hours per year. This translates into lifetimes of just 10 years for this class of traction machines for public applications.
For public applications with the standard load equivalent of p_{EQUIV} = 0,63, some worm or worm helical gear products are capable of 146.000h gear and bearing lifetime, which gives a useful lifetime of 20 years in public applications.

Due to the wear resistant toothing technology used in the *oms*Hypodrive gears, the lifetime of the *oms*Hypodrive as compared to worm gears and worm-helical gears, is limited by the finite lifetime of the bearings only. For the EC 2-25 at an equivalent load of p_{EQUIV} = 0,63, bearing lifetime is 200.000 h, and is reduced to the standard lifetime of 146,000 h for public applications at a very high equivalent load of p_{EQUIV} = 0,80.

This makes the *oms*Hypodrive escalator traction machine EC 2-25 the premier choice for the new generation of public escalator with long lifetimes and high passenger loads.

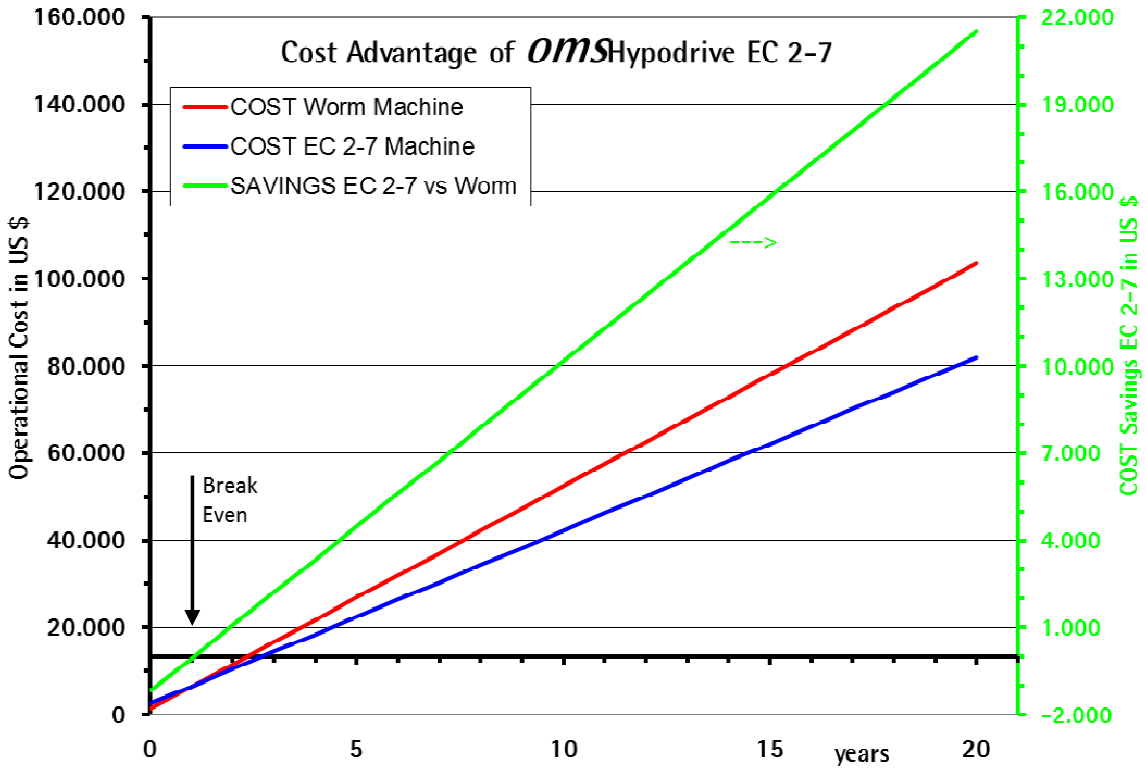
Break Even Point:

The comparison between the *oms*Hypodrive and worm gear drive, both in a commercial application, clearly shows that the efficiency of the hypoid technology in combination with high efficiency motors especially designed for escalator applications, is significantly influencing the break even point of the investment for the escalator traction machine due to its much lower energy usage.

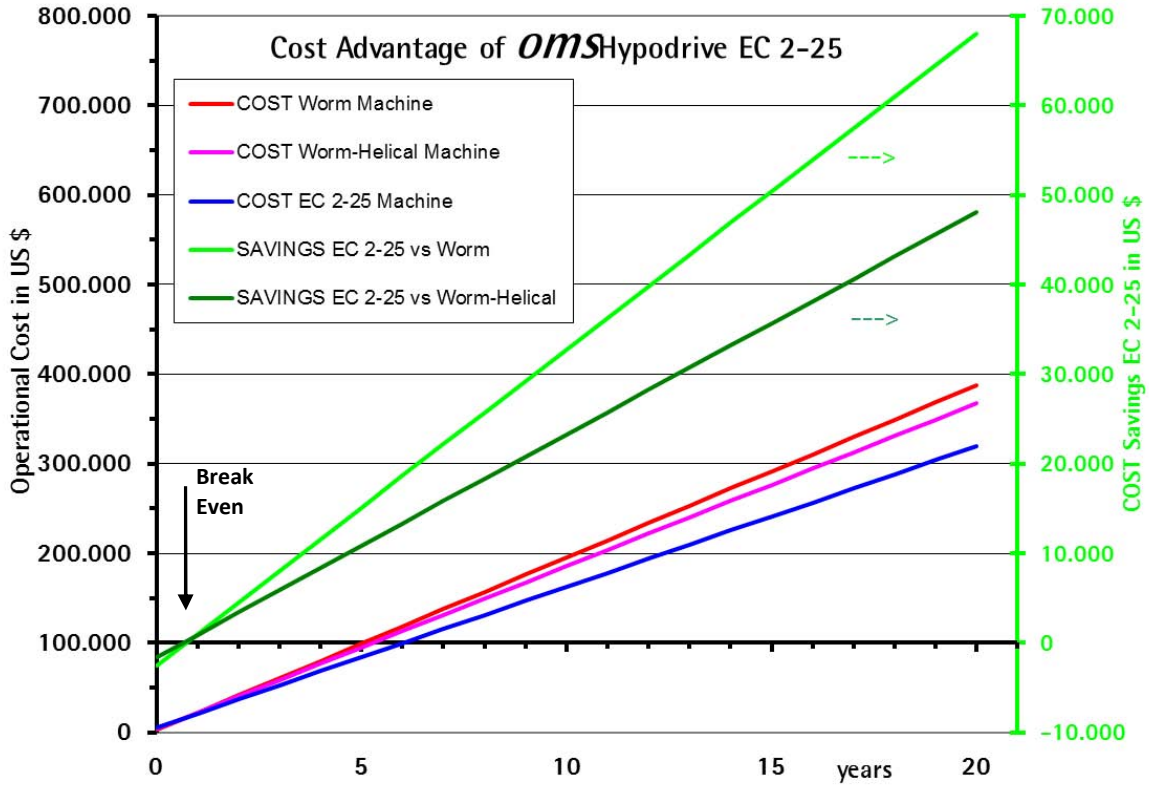
Also a major influencing factor is the oil consumption of the gear box and the associated cost for the oil service. In this respect the *oms*Hypodrive machines deliver an outstanding performance, which is not met by any other currently available technology suited for escalator traction machines of the same performance.

As shown in the following diagrams, all this adds up to realize a break even point of the *oms*Hypodrive machines total cost of ownership as compared to the worm or worm helical based gears in approximately one year. The moderately higher price of the *oms*Hypodrive technology has an almost negligible effect on the total operational cost over the lifetime of the machine.

For the end users of escalators and moving walkways equipped with *oms*Hypodrive traction machines, either in commercial applications like shopping centres and large office buildings, or in public applications like metros, railway stations and airports, both the commercial and technical benefits of the *oms*Hypodrive technology should have become evident now.



Picture 5: EC 2-7 Operational Cost Advantage and Cost Break Even (1 year)



Picture 6: EC 2-25 Operational Cost Advantage and Cost Break Even (< 1 year)

Remarks:

The Difference in the investment of the *oms*Hypodrive and Worm Gear Drive appears to be negligible in view of the difference in operational cost. The higher energy and maintenance cost of a worm gear drive as compared to the *oms*Hypodrive are determining the slopes of the ascending cost graphs. This accumulated difference over lifetime is not only much larger than the cost difference of the two gear types, it is also much larger than the *initial purchasing cost* of either escalator traction machine!

For public applications, although the worm-helical gear has a higher efficiency than a worm gear drive, the superior effectiveness of the *oms*Hypodrive in both efficiency and cost of service is evident, still with substantial savings as compared to a worm-helical drive.
Examples given are for an escalator for commercial applications, with *oms*Hypodrive EC 2-7, and for public applications with *oms*Hypodrive EC 2-25. Both diagrams are based on current unit cost and energy cost as of September 2010.

Conclusions

Savings:
Due to its much better efficiency, its highly optimized gear toothing and its low thermal output, the *oms*Hypodrive gear units achieve a much higher level of usability as compared to a worm gear unit or even worm-helical unit. The *oms*Hypodrive gear units will pay itself off within a very short time of operation.

The cost savings due to the higher efficiency of the *oms*Hypodrive and the lower total cost of service adds up to more than many times the purchasing cost of these escalator traction machines.
Savings for the *oms*Hypodrive EC 2-7 for commercial applications amounts to an astounding saving of more than US $ 22,000 during the machines lifetime of 20 years, as compared to a worm gear drive.
For the *oms*Hypodrive EC 2-25 escalator traction machine for public applications, the cost savings amount to more than US $ 70,000 as compared to a worm gear drive of comparable power, and still has US $ 50,000 lower operational cost, as compared to a worm-helical drive over the lifetime of 20 years of the *oms*Hypodrive escalator traction machine. The respective differences in the initial purchasing cost of the two machine types is already reflected in both diagrams.

Of course the cost savings potential will scale with the power of the escalator traction machine, so for a Tandem machine as pictured on the following page with P = 2 x 30kW, the cost savings potential will of course increase considerably. The EC 2-25 escalator traction machines are available with a power rating up to P = 2 x 33kW at 1.500 min^{-1}, and for this calibre of escalator traction machines the *savings in electricity alone* will amount to an astounding US $ 150,000 over the machines lifetime of 20 years as compared to a worm-helical escalator traction machine of the same output power. Compared to a comparable worm gear based traction machine, the savings in cost of electricity alone will amount to a whopping US $ 235,000 for this class of traction machine. Now one can easily figure out what this will mean in terms of cost savings for a metro station with a multitude of escalators, or what huge operational cost benefits may be expected when extending an existing metro line or building a new metro line.

Environment:
The *oms*Hypodrive machines are environmental friendly escalator traction machines, regarding their minimized usage of resources like energy and lubricants, their low space requirements, low excess heat, low noise emission and vibration.
In our resource hungry world, with continuing price increases for materials and resources, and continuously rising costs for electric energy, this shows very clearly the advantages of using a *oms*Hypodrive gear as the traction machine in escalators.

***oms*Hypodrive escalator traction machines in this respect allow for the first time the design of environmental friendly GREEN ESCALATORS !**

Past, Current And Future Projects:

Consider the savings possible by using *oms*Hypodrive EC 2-25 escalator traction machines when building a new metro line with for example 100 escalators altogether. This is not uncommon these days with new big projects already launched (status 2016):

PROJECT	OMS UNIT	CUSTOMER
Metro Stockholm (65 escalators)	EC 2-25	OTIS Breçlav
Metro London Underground & TfL (> 200 escalators)	EC 2-25	OTIS Breçlav
Metro Delhi (233 escalators)	EC 2-25	OTIS GOEC
Metro Hyderabad (410 escalators)	EC 2-25	OTIS GOEC
Metro Singapore (Tomson line, 411 escalators)	EC 2-25	OTIS GOEC
Metro Riyadh (Line 1 + 2: 429 escalators)	ECT 2-15	ThyssenKrupp Hamburg
Metro Qatar (> 500 escalators)	ECT 2-15	ThyssenKrupp Mieres
Metro Cairo (281 escalators)	EC 2-25	KONE
Metro Paris (EOLE west extension, 167 escalators)	EC 2-25	OTIS GOEC

The savings in operational costs by using the *oms*Hypodrive EC 2-25 escalator traction machine for public escalators in the above example project with 100 escalators will easily amount to **US $ 5,000,000 to US $ 7,500,000** over the period of 20 years, depending on the mix of escalators rise and power, as compared to the next best technology for escalator traction machines.

Picture 7: Tandem EC 2-25, power P = 2 x 18,6kW, 1.500 min^{-1}, OPTION: Handwheel

Appendix

The comparison of the *oms*Hypodrive and worm (worm-helical) gear drives is based on the following assumptions for commercial and public applications, respectively: escalator load is **63%** of nominal load (nominal load: commercial 7.5kW for approx. 4m rise, public 15kW for approx. 9m rise); power input to gear is corrected for by the gear efficiency η; both type of machines use the same type of synthetic gear oil. For the comparison of service cost for *oms*Hypodrive and Worm Gear Drive the cost savings potential due to the reduced handling and depositing cost for the waste oil has not been included.

Escalator for Commercial Applications (70,000 h lifetime)

Average running time of escalator / day	12 h
Average running time of escalator / year	300 days
Average electricity rate in US $/KWh	0.20

	*oms*Hypodrive	Worm Gear Drive
Gear oil volume:	3.5l	15 – 17l
Gear efficiency: η_{GEAR} at 63% load	96%	83%
Motor efficiency: η at n = 1,500min^{-1}, 50Hz, 63% load	90.4% (IE3)	86% (standard)
Total efficiency of gear plus motor: η_{TOTAL}	**86.8%**	**71.4%**
Gear output power to escalator at 63% load: $P_{OUT,\ 63\%}$	4.725 kW	4.725W
Total input power to escalator at 63% load: $P_{OUT,\ 63\%}$	5.446 KW	6.618 KW
Average energy consumption / day: W_{DAY}	65.3 KWh	79.4 KWh
Average energy consumption / year: W_{YEAR}	19,597 KWh	23,824 KWh
Energy cost / year	US $ 3,919.-	US $ 4,765.-

Savings of electricity / year in favour of *oms*Hypodrive **US $ 845.-**

Savings of electricity / lifetime (20 a) in favour of *oms*Hyhpodrive **US $ 16,907.-**

First oil exchange	20.000h (5 years)	1.000h
Oil shelf life	20.000h (5 years)	6.000h
Gear oil volume	3.2l	15l
Oil refill to end of lifetime (70.000h)	**9.6l** (3 x 3.2l)	**195l** (13 x 15l)
Cost of oil for refills during lifetime (at US $ 15 / l)	**US $ 144.-** (9.6l x 15 $/l)	**US $ 2,925.-** (195l x 15$/l)
Cost of Service For refilling oil (at US $ 300 per service)	**US $ 900.-** (1 x US $ 300)	**US $ 3,900.-** (13 x US $ 300)

***oms*Hypodrive** cost savings: lower oil usage US $ 2,781,00 and lower service cost: US $ 3,000.00

Total Savings in Oil-Service / lifetime (20 a)

in favour of *oms*Hypodrive **US $ 5,781.-**

Total cost advantage in favour of *oms*Hypodrive EC 2-7 US $ 22,688.-

Escalator for Public Applications (200,000 h lifetime)

Average running time of escalator / day	20 h
Average running time of escalator / year	365 days
Average electricity rate in US $/KWh	0.20

	*oms*Hypodrive	Worm Gear Drive	Worm- Helical Gear Drive
Gear Oil Volume	13l	25l	23l
Gear efficiency: η_{GEAR} at 63% load	96%	83%	90%
Motor efficiency: η_{MOTOR} at n = 1,500min^{-1}, 50Hz, 63% load	92.1% (IE3)	88.7% (standard)	88.7% (standard)
Total efficiency of gear plus motor: η_{TOTAL}	**88.4%**	**75.4%**	**79.8%**
Gear output power to escalator at 63% load: $P_{OUT, 63\%}$	9.45 kW	9.45 kW	9.45kW
Total input power to escalator at 63% load: $P_{OUT, 63\%}$	10.69 kW	12,53 kW	11.84 kW
Average energy consumption / day: W_{DAY}	214 kWh	251 kWh	237 kWh
Average energy consumption / year: W_{YEAR}	78,037 KWh	91,492 KWh	86,447 kWh
Energy cost / year	US $ 15,608.-	US $ 18,298.-	US $ 17,290.-
***oms*Hypodrive Savings of electricity / year**			
in favour of *oms*Hypodrive		**US $ 2,691.-**	**US $ 1,683.-**
Savings of electricity / lifetime (20 a)			
in favour of *oms*Hypodrive		**US $53,811.-**	**US $ 33,651.-**
First oil exchange	35,000h	1,000h	1.000h
Oil shelf life	35,000h	6,000h	6,000h
Gear oil volume	13l	25l	23l
Oil refill to end of lifetime (146.000h)	**39l** (3 x 13l)	**600l** (24 x 25l)	**552l** (24 x 23l)
Cost of oil for refills during lifetime (at US $ 15 / l)	**US $ 585.-** (39l x 15 $/l)	**US $ 9,000.-** (600l x 15$/l)	**US $ 8,200.-** (552l x 15$/l)
Cost of Service For refilling oil (at US $ 400 per service)	**US $ 1,200.-** (3 x US $ 400)	**US $ 9,600.-** (24 x US $ 400)	**US $ 9,600.-** (24 x US $ 400)
***oms*Hypodrive** :			
cost savings lower oil usage		**US $ 8,415.-**	**US $ 7,675.-**
cost savings lower service cost:		**US $ 8,400.-**	**US $ 8,400.-**
Total Savings in Oil-Service / lifetime (20 a)		**US $ 16,815.-**	**US $ 16.095.-**
Total cost advantage in favour of *oms*Hypodrive EC 2-25		**US $ 70,626.-**	**US$ 49,746.-**