BI-FUEL (DUAL FUEL) CONVERSION OF DIESEL & HFO GENERATING SETS

ComAp Systems

What is and why bi-fuel (dual fuel) conversion?

ECONOMIZE ON THE COST of your power generation by converting your diesel generating sets to BI-FUEL OPERATION

ComAp's simple bi-fuel conversion modifies your original diesel engine so that it uses natural gas as the main fuel – substantially reducing operating costs.

It works by introducing gas to the engine via various technologies and then electronically controlling flow dependent on engine speed and output.

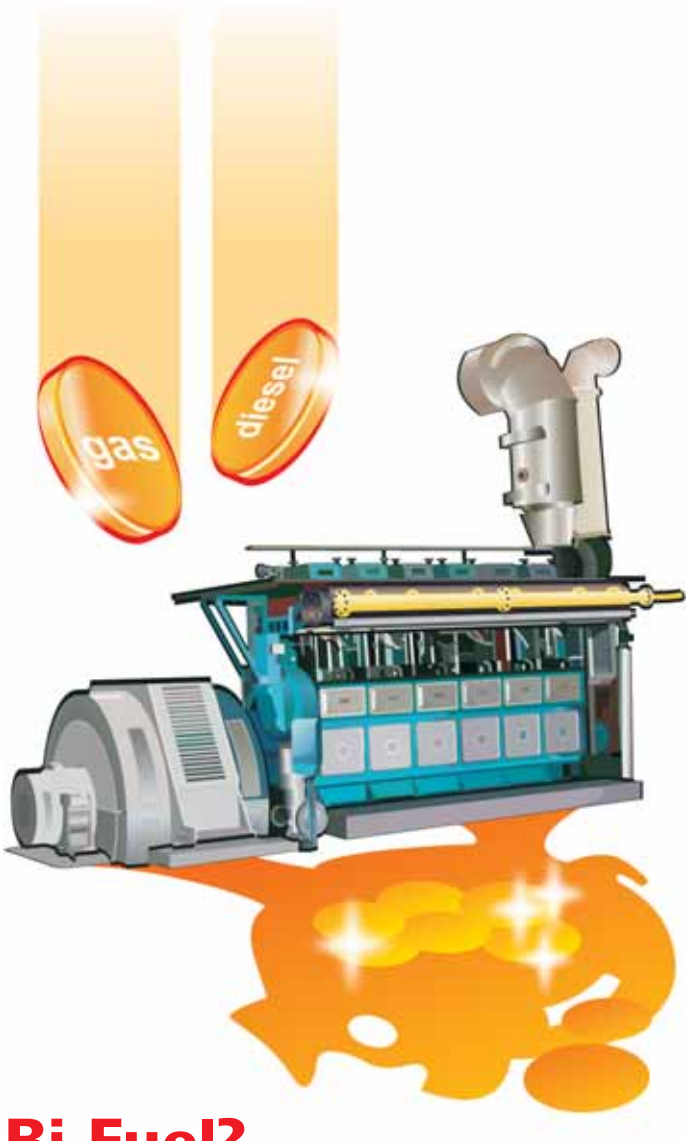
Bi-fuel conversion requires virtually no engine modification and brings double benefits in every application:

- Affordable diesel engines combined with inexpensive natural gas
- Economic solution for slow-speed, middle-speed and high-speed engines
- Flexible use of fuel
- Guaranteed power output
- Efficient and safe operation with lower emissions
- Longer engine life and reduced maintenance costs makes it the perfect investment

Conversion of Diesel Engines to Bi-fuel (two fuels at the same time Diesel/HFO and GAS).

Solutions available for:

- **high speed engines**
  central gas/air mixer (fumigation)
- **slow and middle speed engines**
  individual gas-valve technology



Bi-Fuel? Make BIG savings on your fuel costs!

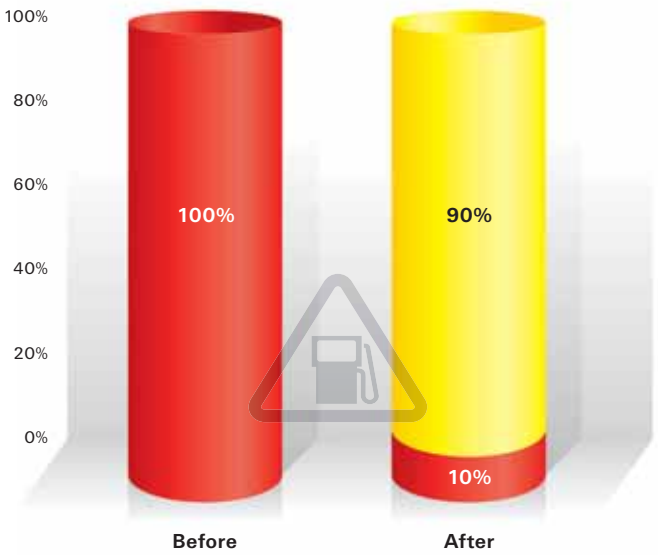
COMMON FEATURES

- Substantial savings on operation costs
- Practically no engine modification required
- Non-derated output power
- Possibility of original diesel operation at any time
- Safe and secure operation
- Lower emissions
- Longer engine life span
- Prolonged service and maintenance intervals

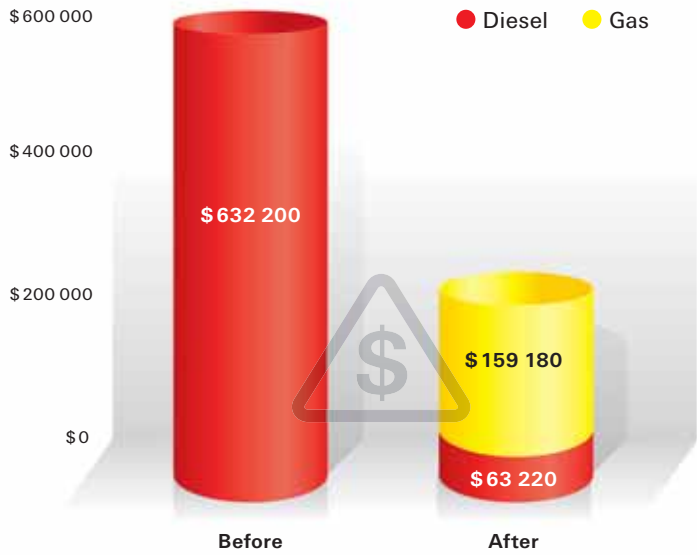
EXAMPLE OF HIGH SPEED ARRANGEMENTS: CUMMINS QSK 60, 1800 kW

CASE STUDY | Conversion of gen-set: ŠKODA (ČKD) 1450 kVA; 375 RPM

- **Substitute up to 90 % of your diesel consumption with gas**
- **Reduce your operational costs substantially**



Fuel consumption at nominal output



Fuel costs per year

Frequently Asked Questions?

What does bi-fuel (dual fuel) operation actually mean?

Bi-fuel (dual fuel) operation means the engine uses two fuels (gas and diesel oil) at the same time. Natural gas is intended as the main fuel and diesel oil is used for the ignition of the gas/air mixture inside the cylinder (a portion of diesel oil is injected at the end of the compression stroke, thereby maintaining the original diesel operation principle).

What methods/technologies are employed in the bi-fuel (dual fuel) conversion provided by ComAp?

ComAp provides two conversion technologies – one for slow/middle-speed engines (up to 1000 rpm) and the second for high-speed engines (1200 to 1800 rpm). Therefore the choice of the appropriate ComAp solution is determined by the engine speed and consequent suction/exhaust valve overlap (i.e. opening of suction and exhaust valves at the same time).

Slow/middle-speed engines normally feature a large valve overlap when the pure air is flushing (cleaning) and cooling the cylinder. After bi-fuel conversion, it is necessary to continue cylinder flushing/cooling by pure air, i.e. gas flow into the cylinder during the valve overlap must be interrupted to avoid the presence of gas in the hot exhaust manifold (this would cause a potentially dangerous situation and result in substantial fuel losses). Therefore, typically for slow and middle-speed engines, each cylinder is equipped with the patented electromagnetic gas valve with variable gas injection timing controlled by a ComAp electronic control system INCON.

In contrast, high-speed engines have only a small valve overlap, so it is possible to install just a central mixer(s) before the turbocharger(s) for the continuous flow of the gas/air mixture. Gas injection is controlled by a throttle operated by the ComAp electronic control system InteliDrive BF according to the required engine output and speed.

Is it necessary to stop the engine in case of required transition between bi-fuel and pure diesel operation modes?

No, transitions between the two modes (from bi-fuel to diesel and vice versa) can be achieved while the engine is running (i.e. without interruption of the load supply) and is a very smooth process. Note the engine will always start on diesel and the operation mode is switched to bi-fuel upon a predefined output level. In case of gas shortage, the transition is immediate and seamless at the actual engine load, gas valves are shut off automatically and the engine continues on pure diesel operation. Once the gas supply has returned the engine is switched back to bi-fuel operation.

Is it possible to operate a converted gen-set on diesel oil only?

Yes, the standard operation mode of the converted engine is certainly bi-fuel. However, operation on diesel fuel only (e.g. in case of gas emergency) remains possible at any time and the converted engine operates using diesel fuel with the same parameters as those before conversion was undertaken.

What is a de-rating factor (output reduction) for a converted gen-set?

After the conversion, the engine nominal output is not de-rated and all engine parameters (e.g. exhaust temperature, engine temperature etc.) and behavior (e.g. response to a load steps) remains within the limits stated by the engine manufacturer for the original diesel engine (provided these parameters were within limits before the conversion). The de-rating factor according to the ambient conditions remains the same.

How does the conversion affect maintenance costs?

Maintenance costs after conversion will not be increased at all. Substantial parts of the engine remain unchanged, new mechanical parts are of heavy-duty design (e.g. service interval for the electromagnetic gas valves is 6000 running hours), and electronic control systems are fully automatic. Moreover, the gas operation means less carbonization of combustion chambers and turbocharger, so that the interval for de-carbonisation and overhauling of the engine is prolonged.

What warranty does ComAp provide for the conversion?

Standard warranty is 12 months from the date of start-up, 4000 running hours, whichever expires earlier. The Warranty covers equipment related to the conversion.

What types of gas can be used for bi-fuel engine operation?

Generally, the most suitable are the Methane-based gases with none or very low contains of Propane such as typically found in Natural Gas. For consulting possible usage of other gas types, please ask ComAp with respective gas specification enclosed.

Can LPG be used for bi-fuel engine operation?

In case of LPG, the bi-fuel conversion is also generally possible, but the situation is different. The LPG has acceptable calorific values regularly, also composition is OK considering there are no aggressive elements (sulfur, hydrogen etc.). The LPG is more explosive than natural gas and therefore it has tendency for so called "knocking", i.e. the LPG starts to autofire when the gas volume, combustion temperature and combustion pressure are higher, i.e. at higher engine loads. Thus, we expect substantial power output reduction after the engine conversion just to avoid knocking. As an example: We have generally calculated that if the LPG consists of 50 % Propane and 50 % Butane, at LPG/diesel ratio 65/35 % the engine power output has to be derated down to 60 % of the nominal output. Of course, exact calculation would have to be done for the specific engine type.

Can CNG or LNG be used for bi-fuel engine operation?

Since CNG and LNG are just highly compressed or liquefied versions of Natural Gas, after sufficient pressure reduction it can be used for bi-fuel engine operation.

Can Biogas be used for bi-fuel engine operation?

Concerning biogas, the bi-fuel conversion of the engine is generally possible. We need to know biogas composition and calorific value to evaluate if the particular biogas type is really suitable. Calorific value may be an issue as biogas is derived from different sources and there is low calorific value in many cases. You can imagine we have to inject sufficient volume of gas into the cylinder to substitute diesel oil (or, better to say, substitute energy delivered by diesel oil). If the calorific value (energy) of the biogas is very low, we would need to inject a larger volume of biogas into the cylinder, which could be technically impossible. Please ask ComAp with respective gas analysis enclosed.

High Speed Engine Conversion System

HOW IT WORKS

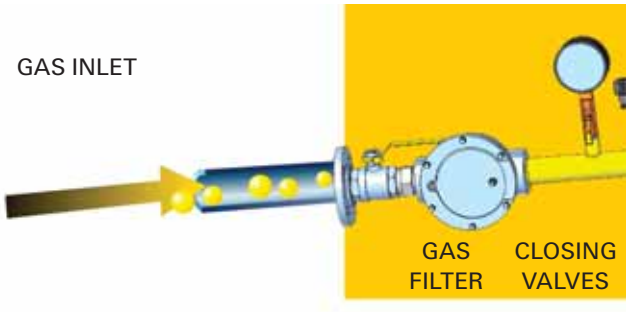
Gas is mixed with air by a common mixer installed before the turbocharger(s). Gas flow is controlled by a throttle valve, which is electronically operated by the ComAp control system InteliDrive BF according to the required engine output and speed.

In order to avoid knocking of the engine, ComAp knocking detector/controller DENOX is installed, thus enabling engine operation at the most efficient gas/diesel ratio.

System for conversion of industrial diesel engines to bi–fuel operation by substitution of typically 50–80% natural gas for diesel.

- Suitable for all High Speed Engines, 1200–1800 RPM
- No reduction of engine power or efficiency
- Smooth transition between diesel and bi–fuel operations at any time
- Gas and air are blended behind air filter before turbocharger by central mixer
- State of the art electronics maximizes the amount of injected gas while keeping all engine parameters within limits specified by the engine manufacturer
- No modifications of internal engine components are required

BASIC SCHEME OF THE CONVERTED ENGINE



MAIN FEATURES

- Completely automatic system
- Cheaper electricity production
- Non–derated output power
- The same response to load steps
- The amount of gas is maximized as much as possible under varying conditions at any time
- High stability and increased protection of the engine
- Lower emissions
- Possibility of pure diesel operation maintained
- Prolonged service intervals
- Turn-key solution
- Easy operation

TYPICAL CONVERTIBLE ENGINES

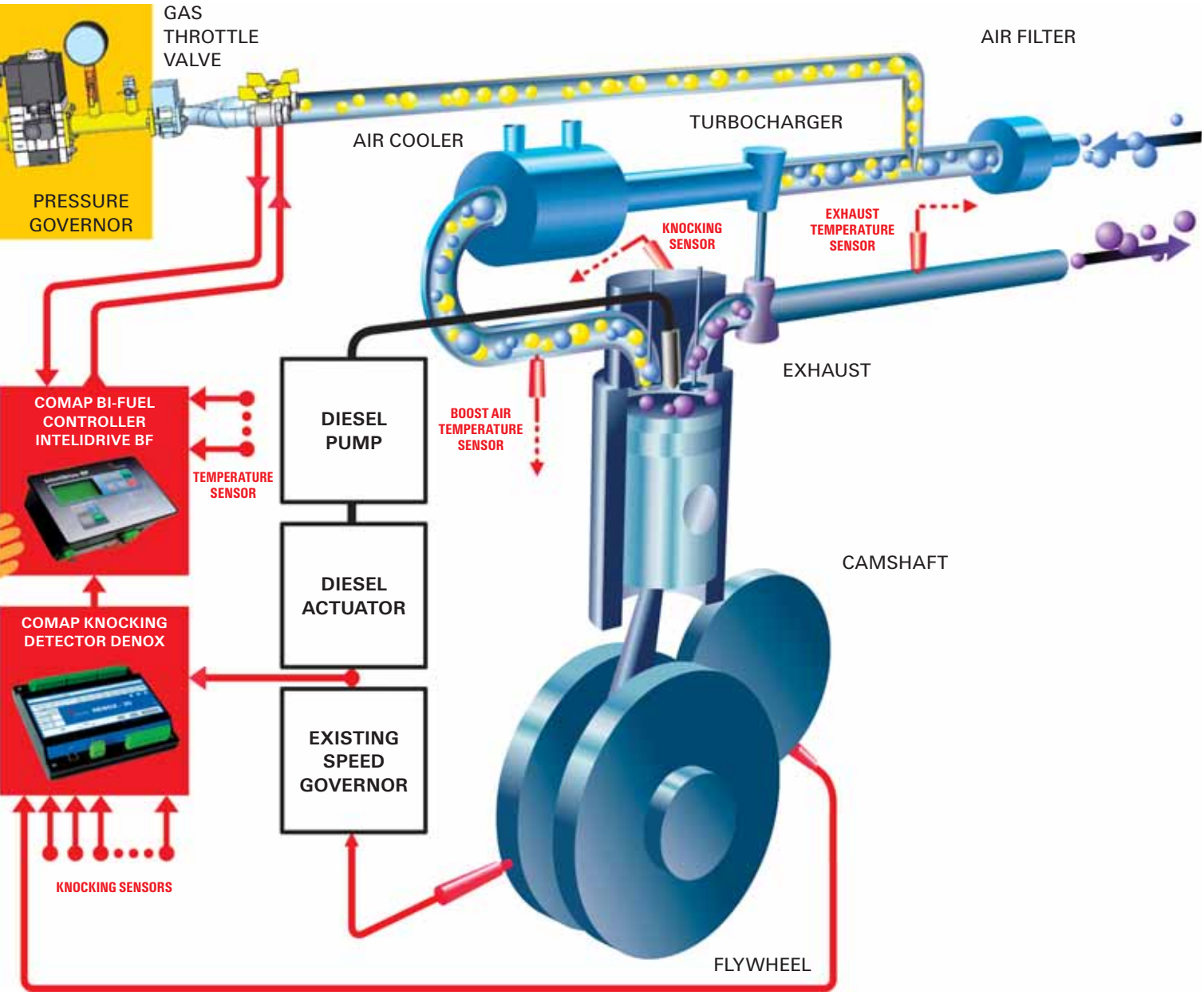
- High-speed (1200 – 1800 rpm)

ELEMENTS OF THE SYSTEM

- Air / gas mixer(s)
- Gas throttle valve with actuator
- ComAp bi-fuel controller/governor InteliDrive BF
- ComAp knocking detector/controller DENOX
- Sensors (acoustic, pressure, temperature, etc.)
- Gas train (gas manifold, gas governor, double closing valve, filter, ball valve etc.)

PRODUCT REPORT | Nigeria, Veepee Industries

In 2004 Company Veepee Industries ordered their first Bi-fuel conversion of an initial 4 generating sets powered by Caterpillar engines - 3412 S/TA, and 3508, with varying outputs of 800kVA to 1000kVA, so impressed with the substantial savings resulting from the achieved gas diesel ratio of 65 % gas / 35 % diesel using the ComAp High Speed Bi-fuel solution the company then ordered an additional 7 engines to be converted to ComAp bi-fuel operation. These engines have continued to operate most reliably over the years. As the company has expanded, the 100 % support of ComAp Bi-fuel solutions by Veepee has been ongoing.



Bi–fuel controller InteliDrive BF

Gas Throttle Valve

Knocking detector DENOX

Gas/ Air Blender

Slow & Middle Speed Engine Conversion System

HOW IT WORKS

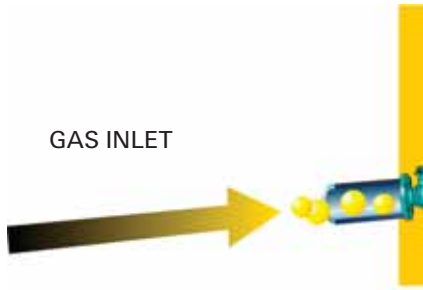
Gas is injected into the cylinder inlet manifold by individual gas electromagnetic valves installed as close to the suction valves as possible. The electromagnetic valves are separately timed and controlled by the ComAp injection control unit INCON.

This system interrupts the gas supply to the cylinder during the long overlap of the suction and exhaust valves (typical for slow-speed and medium-speed engines – while the valve overlap cylinder scavenging is performed). This avoids substantial gas losses and prevents dangerous gas flow to the exhaust manifold.

System for conversion of industrial diesel engines to bi–fuel operation by substitution of typically 60–90% natural gas for diesel or HFO.

- Suitable for engines with speed below 1000 RPM and output above 500 kW
- No reduction of engine power or efficiency
- Smooth transition between diesel and bi–fuel modes at any time
- Gas is injected directly before intake valve by high speed electromagnetic valves, one valve per cylinder
- No modification of internal engine components is required
- Automatic equalization of exhaust gas temperatures from individual cylinders

BASIC SCHEME OF THE CONVERTED ENGINE



MAIN FEATURES

- Completely automatic system
- Extremely efficient operation – only very small percentage of diesel is necessary
- Cheaper electricity production
- Non-derated output power
- The same response to load steps
- High stability and increased protection of the engine
- Lower emissions
- Possibility of pure diesel operation maintained
- Prolonged service intervals
- Individual approach
- Turn-key solution
- Easy operation

TYPICAL CONVERTIBLE ENGINES

- Slow-speed (up to 750 rpm) turbocharged
- Middle-speed (around 1000 rpm) turbocharged

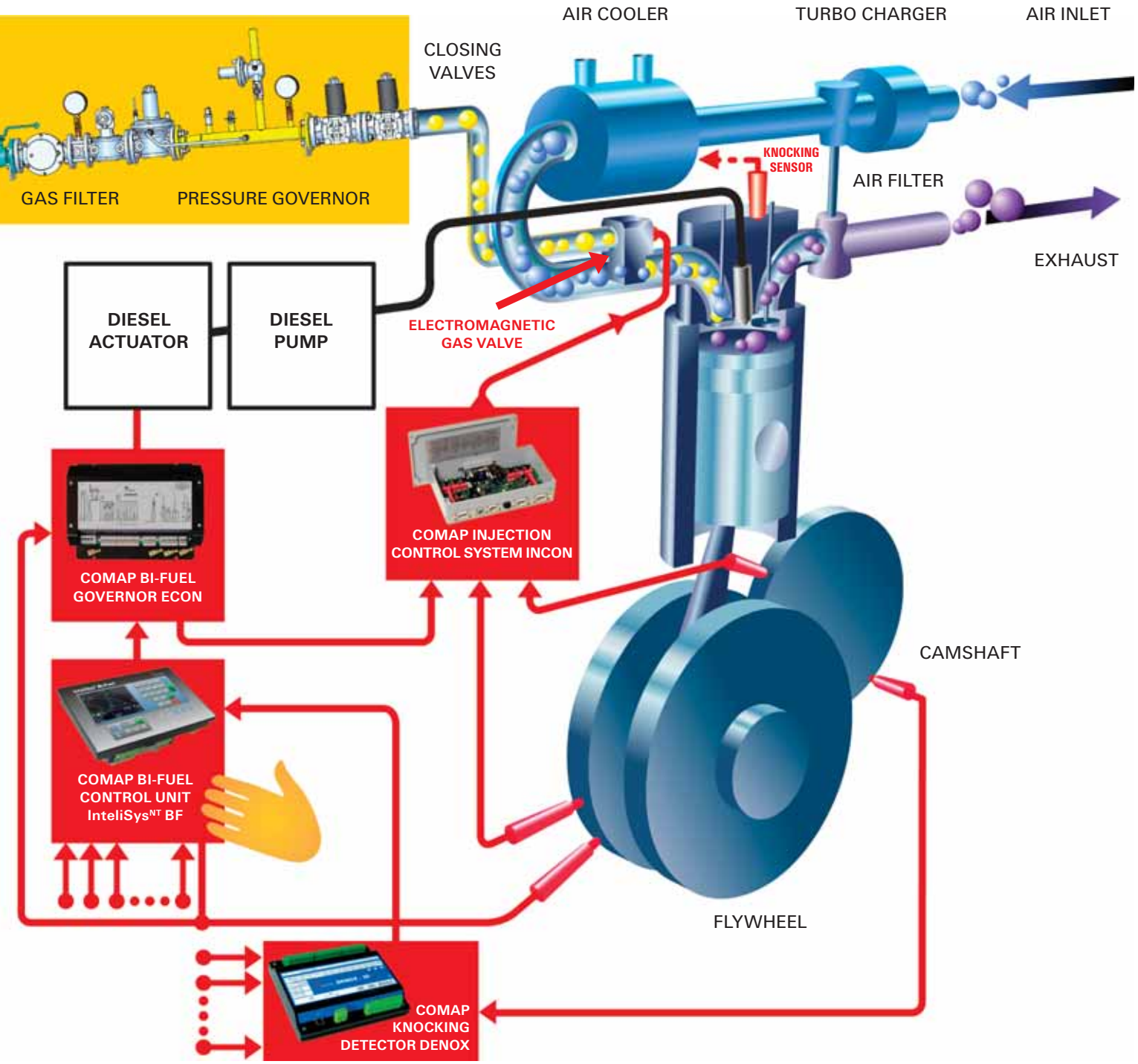
ELEMENTS OF THE SYSTEM

- Gas admission valves
- ComAp electromagnetic valves control unit INCON
- ComAp Bi-Fuel automatic control unit InteliSys^{NT} BF
- ComAp bi-fuel governor ECON
- Safety valve(s) for air filling manifold
- Gas train (gas manifold, gas governor, double closing valve, filter, ball valve etc.)
- ComAp knocking detector/controller DENOX

PRODUCT REPORT | Nigeria, Spintex Mills

In December 2006 company Spintex Mills converted 4 of their ŠKODA (ČKD) 9TS35-50/2 powered generating sets to Bi-fuel operation using the ComAp slow speed individual gas valve technology with INCON system and ENCON Bi-fuel governor resulting in a gas diesel ratio of 80% gas / 20% diesel ignition portion.

Spintex Mills then went on to order further slow speed and High speed ComAp bi-fuel systems and have continued to benefit from the ongoing financial savings and additional many advantages the ComAp solutions have provided them.



Engine control unit InteliSys^{NT} BF

Injection Control System Incon

Bi–fuel governor ECON

Electromagnetic gas admission valve

Knocking detector DENOX

Worldwide References

OVERVIEW

ComAp can simply convert any engine type or model to Bi-fuel operation. Following are some examples of converted engines.

CZECH REPUBLIC

Phoenix Zeppelin – CAT DEALER, CAT C18, CHP Power plant

NIGERIA

Lucky Fibres Nigeria Ltd. – ŠKODA (ČKD) – 9TS 35-50/2 – 1160kW

UNITED ARAB EMIRATES

Dubai – Caterpillar Motoren MaK/Rak Ceramics
2× MaK 16M32 7200 kW – HFO engines

INDONESIA

PT. Mitsubishi Chemical – 4× Niigata 16V32CX 5500 kW engines

Central gas/air mixer for high speed engines

Engine Brand	Engine Type	DG set Output
Caterpillar	3300 series	150 kW - 220 kW
Caterpillar	3400 series	200 kW - 650 kW
Caterpillar	3500 series	700 kW - 2000 kW
Caterpillar	C18 series	400 kW - 500 kW
Cummins	KTA series	400 kW - 1200 kW
Cummins	QST series	650 kW - 800 kW
Cummins	VTA series	500 kW - 600 kW
Deutz	TBD series	all outputs
MAN	D2842LE201	400 kW
Mercedes	OM444LA/12183TB83	440 kW
Perkins	3012TAG2A	580 kW
SCANIA	DC series	225 kW - 520 kW
Volvo	TD series	all outputs

Individual gas-valve technology for slow & middle speed engines

Engine Brand	Engine Type	DG set Output
Hyundai - HIMSEN	6H21/32	1128 kW
MaK	8M 332 AK	1200 kW
MaK	8M453	2000 kW
Niigata	6L32CLX	2000 kW
Pielstick	18PC2V	6000 kW
Ruston	12RKC(H)	1800 kW
SKL	8NVD	920 kW
ŠKODA (ČKD)	6S350PN	700 kW
ŠKODA (ČKD)	9TS35-50/2	1160 kW
ŠKODA (ČKD)	6-38A6S	1816 kW
ŠKODA (ČKD)	12C28GSW	2300 kW
Wärtsilä	SWD 9FHD 240	1200 kW
Wärtsilä	9 FHD 240 G	1596 kW
Wärtsilä	Nohab 16V25	2280 kW
Wärtsilä	12V32E	3850 kW
Niigata	16V32CX	5000 kW

CUSTOMER FEEDBACK

CO-OPERATION AND APPROVAL BY MAJOR ENGINE PRODUCERS

Due to ComAp's vast experience in bi-fuel conversion of existing engines and also in electronic control of brand new bi-fuel and gas engines, many Original Engine Manufacturers have established close cooperation with ComAp in this field.

* For complete and detailed list of actual OEM's please contact ComAp.

Proven Technology and Reliability!

COMPANY	PT. Friesland Food Indonesia
COUNTRY	Indonesia
CONVERSION	6 units of Caterpillar 3512B

In July 2006, ComAp commissioned one new Caterpillar 3512B engine for PT. Friesland Food Indonesia; upon complete satisfaction the customer decided to order the conversion of another 3 new Caterpillar 3512B engines.
In 2008 PT. Friesland Food Indonesia purchased 2 more new Caterpillar 3512B powered gensets for their increasing load demand and once again further ordered another 2 Bi-Fuel conversion kits for these additional engines.
All 6 converted units have been running on Bi-fuel to date providing the customer with substantial ongoing savings for the life of these engines.

ORIGINAL PARAMETERS (before conversion)

Fuel	Diesel
Nominal gen-set output	1200 Kw
Real output on site	800 Kw

PARAMETERS AFTER CONVERSION (dual-fuel)

Fuel	Gas + Diesel
Gas / Diesel ratio	60 / 40 %
Nominal gen-set output	1200 Kw
Real output on site	800 Kw

Investment payback period
3 MONTHS

COMPANY	Barrick Gold Corporation; Osborne Mine
COUNTRY	Australia, Queensland
CONVERSION	5 units of Wartsila 12V32E

In December 2008 ComAp completed a very prestigious bi-fuel conversion project for Barrick Gold Corporation at their Osborne Mine site in Australia. The Osborne underground copper-gold mine is located in the state of Queensland in north-eastern Australia. The mine site has 5 × Wartsila 12V32E powered, 3850 kW generating sets that were operating solely on Diesel fuel oil before the conversion; the diesel generators provided all power to the mine site for their operations that has large varying load swings.
ComAp then converted all 5 engines to bi-fuel operation.
By simply replacing large percentages of the engines diesel use with the available natural gas on site, the Osborne site now benefits from substantial financial savings because of the lower cost of natural gas compared to diesel fuel.

ORIGINAL PARAMETERS (before conversion)

Fuel	Diesel
Nominal gen-set output	3850 kW
Real output on site	3300 kW

PARAMETERS AFTER CONVERSION (dual-fuel)

Fuel	Gas + Diesel
Gas / Diesel ratio	75 / 25 %
Nominal gen-set output	3850 kW
Real output on site	3300 kW

Investment payback period
3 MONTHS

About ComAp?

"ComAp is a dynamic international company with a solid reputation for delivering innovative solutions to the power generation electronics market. By providing customers with state-of-the-art products, ComAp has built a name for delivering excellent reliability and good value."

Libor Mertl
Managing Director

ComAp was founded in 1991 in Prague. Since then ComAp has specialized in engine and gen-set electronics developing several lines of gen-set control systems, anti-knocking detectors, misfiring detectors, gas injection controllers, engine management systems etc.

The first conversions of diesel engines took place in 1995, on slow speed ŠKODA (ČKD) engines. Since then ComAp continues to serve customers throughout the world delivering products that offer a proven and reliable solution.

Within the last decade ComAp has become recognized as the leader in many of its core areas and is now the world's largest supplier of turn-key bi-fuel solutions and bi-fuel conversion components.

ComAp's key advantage is our flexibility, experience, knowledge and enthusiasm in all of our three product lines:

- Electronic products for the power generation industry
- Turn key electronic and electric solutions for power generation industry
- Bi-fuel conversion solutions

The managements task is to keep and strengthen this advantage by helping our customers solve their problems and in doing so keep our customers fully satisfied with excellent service.

Within our company we work towards establishing a pleasant and friendly atmosphere designed to support the creativeness, dynamics and courage in finding new opportunities, projects, solutions and technologies. We will always deal honestly and fairly with our partners and personnel.

Certification

All ComAp products meet the most rigorous standards during manufacture, with every stage being undertaken in accordance with ISO certification, which was obtained in 1998.


CERTIFICATE

ISO 9001:2000

Followed by the marine Germanischer Lloyds approval in 2001, ComAp continue to work toward the highest levels of certification with on-going co-operation and support with both international and domestic ISO 9001 partners.

Accreditation brings confidence, and every ComAp product is supplied with the appropriate warranty and after-sales support for complete peace of mind.

Research and Development

ComAp believe passionately in the importance of continuously developing new technology along with forward thinking software and hardware to maintain the enviable position as worldwide leader in gen-set control and communication solutions.

At the heart of this process is a desire to find better solutions for customers, and draw upon the company's most valuable asset – people. Over 80 % of ComAp employees are graduates with specialist electronic and programming knowledge appropriate to the innovative development of market-orientated engine management systems.

This unique know-how is matched by ComAp's significant investment at every stage of the research and development process resulting in the creation of leading-edge modern development facilities.

Training

Complete and full technical training can be provided to suit your needs, and level of understanding either at ComAp facilities or at your own – wherever you are in the world. This is backed by our commitment to offer full service and product installation if required.

ComAp training is tailor-made to your needs and is designed to ensure you get the most from your ComAp equipment and covers all aspects of operation and equipment use. Further help is provided online at www.comapsystems.com with ComAp specialists always willing to help whether it be consultancy or technical support.

ComAp on-line

The ComAp website **www.comapsystems.com** provides more information about our company, history and services.

It is also the best place to visit for up-to-date news on existing product development, new product launches and free software downloads.

The easiest way to stay informed is to join the *ComAp Systems Members Club*, which you can do by simply completing the registration page on our website.

ComAp
Systems

Manufacturer

ComAp, spol. s r. o.

Kundratka 2359/17 • 180 00 Praha 8 • Czech Republic

Phone: + 420 246 012 111 • Fax: + 420 266 316 647

info@comap.cz • www.comapsystems.com

Local Distributor / Partner

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