

Dan F. Christiansen

Fra: Hgsted, Per (INNIO, Non-GE) <per.hogsted@ge.com>
Sendt: 7. oktober 2019 14:49
Til: Dan F. Christiansen
Emne: SV: Motordrift på forgasningsgas.
Vedhæftede filer: 1000-0300_en.pdf

Hej Dan,

Hermed fremsendes som aftalt vor krav til gassen.

Med hensyn til H₂S kan jeg oplyse, at grænsen ligger på 700 mg/Nm³ ved 10 kWh eller 200 mg/Nm³ ved 10 kWh. Hvilken grænse som anvendes, er afhængig af motorens Serviceplan og version.

Jeg omregner de f.eks 200 mg/Nm³ ved 10 kWh på følgende måde:

$200 : 10 \times \text{brændværdi i kWh} : 1,52 = \text{ppm H}_2\text{S}$

Ved eksempel på 2,0 kWh i brændværdi;

$200 : 10 \times 2,0 : 1,52 = 26 \text{ ppm H}_2\text{S}$

Se eksempel i vedhæftede fil på side 20-21 omkring H₂S

Hører med interesse fra dig.

MVH
Per

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Jenbacher gas engines

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Fra: Dan F. Christiansen <dfc@DanskEnergiRaadgivning.dk>
Sendt: 26. september 2019 14:29
Til: Hgsted, Per (INNIO, Non-GE) <per.hogsted@ge.com>
Emne: EXT: Motordrift på forgasningsgas.

Kære Per,

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Hermed mail som lovet.

Lidt om vores projekt;

Termisk konvertering med fokus på restprodukter.

Vores forgasser-system er designet specielt til restprodukter. (fiberfraktion fra biogasproces – spildevandsslam – osv.)

Målet er at kunne fremstille en gas der er så ren at den umiddelbart kan anvendes som brændstof i en gasmotor eller til proces, f.eks. til katalytisk fremstilling af biofuels.

Selve forgasningsprocessen er ny og alle parametre at styret således kontinuerlig drift er mulig, og produktion af gas uden

langkædede tjæreforbindelser.

Status:

Prototypen er bygget og blevet testet på DTU Risø i år 2018.

Vi har netop færdiggjort et filtersystem. Resultaterne af gas- analyserne viser at stort set alt H_2S bindes i filtersystemet Der er dog lidt carbonylsulfid COS og carbondisulfid CS_2 tilstede efter filteret. Det er derfor planen og tilføje endnu en filterkolonne

for således at opnå en fuldstændig eliminering af samtlige svovlkomponenter i produktgassen.

(denne filterkolonne bliver et vådt basisk filter med lang opholdstid og nedkøling af gassen til under $10\text{ }^\circ\text{C}$)

Under afbrænding af den filtreret gas er flammen usynlig i dagslys, og kun et kraftigt varmemflimmer indikerede energiomsætning.

Vores gassammensætning er pt. typisk; 22 vol. % H_2 - 22 vol. % CO - 2 vol. % CH_4 . Derudover CO_2 samt nitrogen.

Nitrogenniveauet kan reduceres hvis forgasseren gøres 100 % oxygenblæst, men ikke elimineres totalt da en del N naturligvis

frigøres fra brændslet. CO_2 kan bindes med Aminvæske og således op koncentrere gassens brændværdi.

Det er vores plan at bygge et pilotanlæg på ca. 150 kW (20 X prototypen)

Mit spørgsmål;

Hvilken krav stille I til svovlindholdet i gas til motordrift ?

Med venlig hilsen

Dan F. Christiansen.

GGC-Tech / B2G

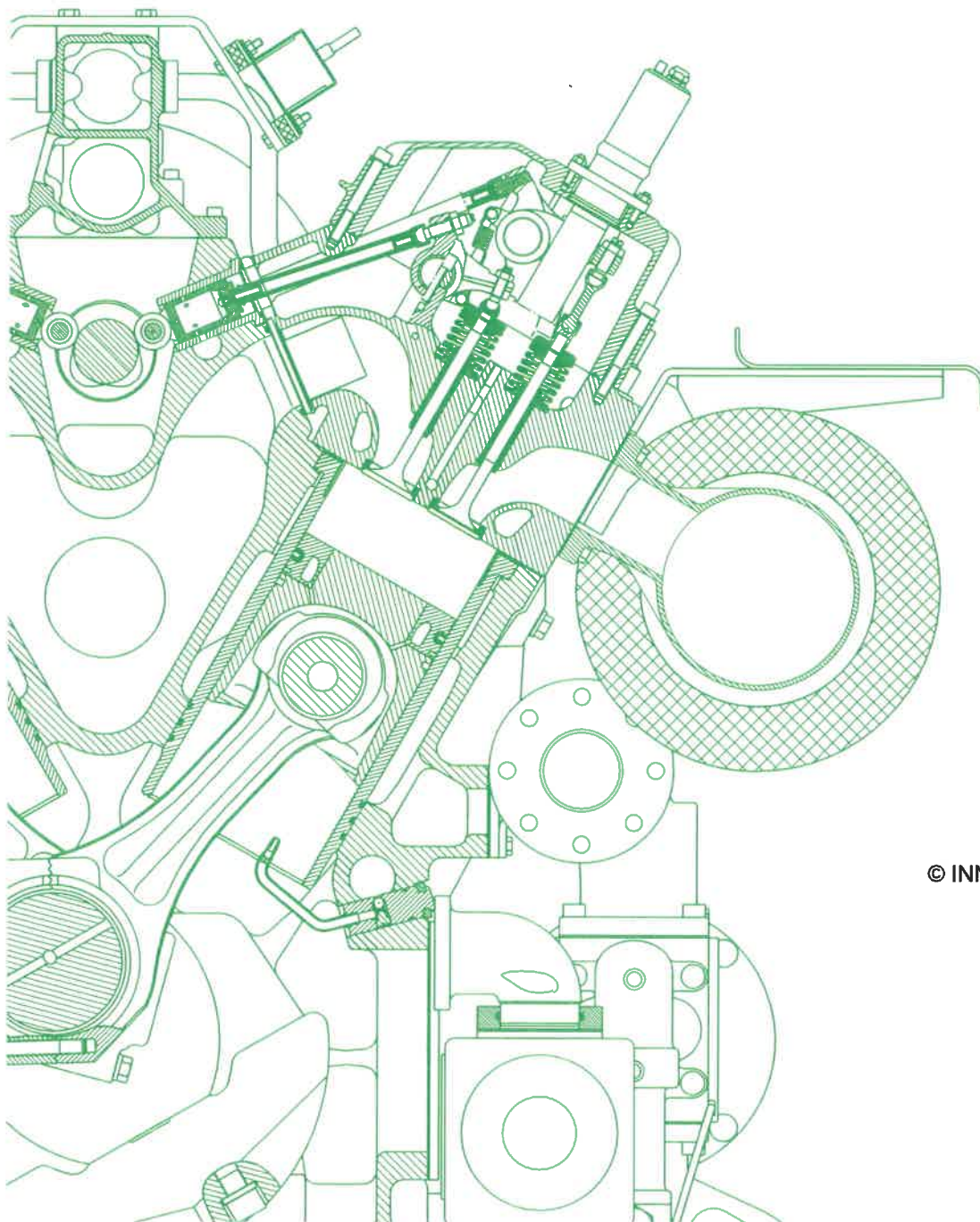
Tlf. 2437 5063



TA 1000-0300

Technical Instruction

Fuel gas and combustion air requirements



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Humidity content in gH ₂ O/kgAir	Effect
≤ 15	No condensate formation and therefore no influence on engine operation expected
> 15	Check the reduction diagram

The following requirements and limits are placed on the combustion air:

Requirements and limits for the combustion air

Designation	Additional	Limitation	Unit	Note
temperature				See TA 1100-0110
Particles Total particle content		≤ 0.1	mg/Nm ³	Type 2 to 6: Purity class G3 as per EN779 J920: purity class M6 as per EN779 (previously F6) A filter in the combustion air intake protects the system against particles. The value specified is the design basis for the air filter ¹⁾
Highly-flammable components				Safety limits must not be exceeded. If the combustion air is not free of highly-flammable components, its usability must be agreed with Jenbacher.
Acid-forming and base-forming constituents				Must not enter the engine


¹⁾ If the filter service life stated in the maintenance plan is not reached or if the filter service life turns out to be unacceptable, the customer must take measures to improve it.

If the ambient air contains impurities (such as sulphur compounds, oil vapours, other gaseous constituents, etc.) its usability must be checked.

Care must be taken to ensure that the location where the combustion air is aspirated is not subject to any microclimate, such as warm humid zones in greenhouse applications. It must also be ensured that emissions from a wide variety of sources such as industrial air outlets, emissions from biogenous processes or solvents cannot enter the engine intake air and therefore cannot have any effect on engine operation. Jenbacher engine plants require a special air intake system which is described in the following Technical Instruction together with further boundary conditions:

- TA 1100-0110: Boundary conditions for GE Jenbacher gas engines

⚠ ATTENTION



Draught effect
When the engine is at rest, note that depending on the design of the intake system and the chimney draught effect, air may be permanently drawn through the engine. This means that the engine is exposed to ambient air even when shut down, which can result in damage if the air quality is poor.

5.3 Requirements and limits for the mixture

Jenbacher engines and plants must be protected generally against the ingress of unwanted substances into the mixture via both the fuel gas and the combustion air.

Limit values for trace substances and impurities, oil, condensate and particles

Trace substances and impurities usually enter the gas during the gas formation process, but can also come from the ambient air. They are usually impurities in the ppm range. The effects of trace substances and impurities do not become noticeable until the engine has been in operation for a certain time (cumulative effect). The same applies to oil, condensate and particles. As these effects are predominantly harmful, both the fuel gases and the ambient air should be as free as possible of trace substances and impurities. If the impurity content in the fuel gas is very high, suitable fuel gas cleaning may, under certain circumstances, be the best method of ensuring economic utilisation of the fuel gas.

To determine the suitability of a fuel gas for use in combustion engines, comprehensive knowledge of the gas analysis is required. Field experience shows that even results that were obtained under the same operating conditions can vary substantially. The effect of trace elements can therefore only be predicted to a certain extent, as very complex interrelations and cause/effect relations are often involved. In principle, the effects of trace elements are proportional to the quantity fed into the engine while it was operating. When using a fuel gas with a high calorific value, the gas flow to the engine is smaller compared with a gas with a low calorific value. As a result, the amount of trace substances introduced into the engine - and therefore their effect - differs even if there are identical concentrations of trace substances in the fuel gas. In order to be able to compare various gases, the trace substance concentration values must be related to a certain fuel gas energy amount (the fuel gas output required to generate a certain engine output is very similar for all gas types).

Jenbacher has therefore set the energy content of 1 standard cubic metre of methane to 10 kWh (rounded off).

The combustion air requirement also depends on the fuel gas and its calorific value. This results in a specific fuel gas to air mixture ratio for the gas types, which can be seen in the Appendix.

Additional trace elements or impurities not explicitly mentioned or limited in this Technical Instruction can change the properties of the fuel gas. Jenbacher does not accept responsibility for reduced output, reduced efficiency, reduced availability or possible engine damage resulting from such additional trace substances or impurities. In such cases Jenbacher is also relieved of any and all warranty obligations.

Limit levels for trace substances and impurities ¹⁾

Designation	Additional	Limitation	Unit	Note
Total sulphur	S	≤ 700	mg/10 kWh	Note effect on oil service life ²⁾
		≤ 1200	mg/10 kWh	With limited warranty ³⁾
Halogen compounds	Total Cl + 2 x F	≤ 100	mg/10 kWh	Note partial load operation ⁴⁾
		≤ 400	mg/10 kWh	With limited warranty ³⁾
Ammonia	NH ₃	≤ 50	mg/10 kWh	Higher NH ₃ values in the fuel gas may result in the NO _x values for the engine exhaust gas stated in the specification being exceeded.
VOSC as total silicon	Total silicon as Si _{BG} (silicon operational limit value)	≤ 0.02		The operational value of silicon Si _{BG} to be determined exactly by means of an oil analysis ⁵⁾
Highly flammable components	Acetylene (C ₂ H ₂) carbonyl sulphide (COS)	≤ 0.02	vol%	These substances can cause uncontrolled spontaneous combustion in the system!
		≤ 0.02	vol%	

¹⁾ The limit values quoted in the following sections apply if Jenbacher fuel gas or exhaust gas treatment systems are used, or if engines are being used with a pre-chamber gas system, or if the system is installed in tropical zone countries.

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2. The fuel gas supply must have been up and running without interruption for at least three (3) hours. The gas volume flow must be at least 75 % of the operational gas flow that would be needed at full-load condition of the projected gas engine installation. With gas lines having a reduced flow during sample there is the risk of a faulty measurement when trace components condens on cold surfaces and/or when silicon-organic compounds are absorbed in other condensed trace components.
3. The sampling location should preferably be in the pressurised part of the fuel gas line upstream of the projected engine is reached. However, sample taking in negative pressure lines is also possible.
4. During this period, landfill gas installations require the suction pressure to be approximately the same as the suction pressure during the projected full-load operation. Landfills which produce no gas flows in the volumes required for the projected engine operation cannot be sampled satisfactorily. In the case of landfills, suitable samples can only be taken in a gas collecting line. Sample taking from individual sources will not yield results that can be used as described in this Technical Instruction.
5. In order to achieve a fuel gas trace element load that is as constant as possible, none of the settings of the operational gas installation should be modified during sample taking.

6.7 Note about the mixture

Polluted combustion air may be used in individual cases provided that the pollutants it contains are not already present in the fuel gas in the maximum permitted concentration. Note here that the mixture ratio is dependent on the fuel gas composition and determines the specific combustion air requirement. The mixture ratio is roughly 4 for gases originating from gasification processes, and this means that the fuel gas must be mixed with approximately 4 times its volume of combustion air. The figure for this ratio for natural gas or propane is more than 20. The Table below shows approximate mixture ratios for individual gas types.

Fuel gas	Mixture ratio of combustion air to fuel gas (approximate, depends on the project)
Natural gas (NG)	22
Associated petroleum gas (APG)	13
Biogas, sludge gas, landfill gas (BG)	8
Coal mine gas (CMG)	10
Gases from gasification processes (GG)	4
Process gases (PG)	8
Liquid gas, propane gas (LG)	24

This shows that the ingress of harmful substances via the combustion air (with the same concentrations as in the fuel gas) can lead to significantly more severe damage to the engine.

This means that the sulphur limit of 700 mg/10 kWh applicable to fuel gas can be converted to the combustion air using the mixture ratio. For example, a sulphur limit of 88 mg/Nm³ for the combustion air can be calculated for an engine running on biogas, provided that the fuel gas is totally free of sulphur! The mixture ratio contains the conversion of [mg/10 kWh] in [mg/Nm³].

The following Appendix shows a calculation example for a plant with polluted fuel gas and polluted combustion air.

6.8 Sample calculations

Sample calculation trace substance concentration SC

Measured concentration [mg/Nm³]

$$SC = \frac{\text{Calorific value [kWh/Nm}^3]}{\text{Calorific value [kWh/Nm}^3]} \times 10$$

Concentrations are frequently indicated in volume-related quantities e.g. ppm (parts per million), which must be converted in an intermediate step to mg/Nm³ using the density under normal conditions: i.e.

$$SC' \text{ [mg/Nm}^3] = \text{Measured concentration [ppm]} \times \text{element density [kg/Nm}^3]$$

Remark: expressing the quantity as ppm (= 10⁻⁶) and conversion from kg to mg (10⁻⁶) cancel each other out.

Calculation example for biogas

CO ₂	40%
CH ₄	60%
H ₂ S	260 ppm (at normal density condition = 1.52 kg/Nm ³)
Lower calorific value	6 kWh/Nm ³ (= 60% of 100% CH ₄ = 10 kWh/Nm ³)

Step 1: conversion of measured value in ppm to mg/Nm³, referred to H₂S

$$SC'_1 \text{ [mg/Nm}^3] = 260 \text{ [ppm]} \times 1.52 \text{ [kg/Nm}^3] \qquad SC'_1 = 395 \text{ mg/Nm}^3$$

Step 2: conversion of the value in relation to H₂S to the limited sulphur value in mg/Nm³

$$SC' \text{ [mg/Nm}^3] = \frac{\text{Sulphur molar mass}}{\text{Molar mass of H}_2\text{S}} \times SC'_1 \qquad SC' \text{ [mg/Nm}^3] = \frac{32}{34} \times 395 \text{ [mg/Nm}^3]$$

$$SC' = 372 \text{ mg/Nm}^3$$

Step 3: conversion of measured value in mg/Nm³ to comparison value (mg/10 kWh).

$$SC = \frac{372 \text{ [mg/Nm}^3]}{6 \text{ [kWh/Nm}^3]} \times 10 \Rightarrow SC = 620 \text{ mg/10 kWh actual value}$$

$$\text{Without catalytic converter} \Rightarrow SC_L = 700 \text{ mg/10 kWh} \qquad SC < SC_L \Rightarrow \text{OK}$$

In principle, this sample calculation also applies to all limit values expressed as mg/10 kWh.

Calculation example for a plant with polluted fuel gas and polluted combustion air

The combustion air for the biogas plant in the above example contains sulphur dioxide (SO₂) in a concentration of 12 mg/Nm³.

Step 1: conversion of the value referred to SO₂S to the limited sulphur value in mg/Nm³

$$SC'' \text{ [mg/Nm}^3] = \frac{\text{Sulphur molar mass}}{\text{SO}_2 \text{ molar mass}} \times SC''_1 \qquad SC'' \text{ [mg/Nm}^3] = \frac{32}{64} \times 12 \text{ [mg/Nm}^3]$$

$$SC'' = 6 \text{ mg/Nm}^3$$

Step 2: calculation of the additional sulphur ingress via the combustion air

For biogas, the mixture ratio of combustion air to fuel gas is 8. The mixture ratio contains the conversion of [mg/Nm³] in [mg/10 kWh].

$$SC_{\text{air}} [\text{mg}/\text{Nm}^3] = SC'' \times \text{mixture ratio} \quad SC_{\text{air}} = 6 [\text{mg}/\text{Nm}^3] \times 8 [\text{mg}/10 \text{ kWh}] / [\text{mg}/\text{Nm}^3]$$

$$SC_{\text{air}} = 48 \text{ mg}/10 \text{ kWh}$$

Step 3: calculation of the total sulphur ingress

$$SC_{\text{tot}} = SC + SC_{\text{air}} \quad SC_{\text{tot}} = 620 [\text{mg}/10 \text{ kWh}] + 48 [\text{mg}/10 \text{ kWh}]$$

$$SC_{\text{tot}} = 668 \text{ mg}/10 \text{ kWh}$$

$$SC_{\text{tot}} < SC_L \Rightarrow \text{OK}$$

Sample calculation for converter gas

Main gas components	Value	Unit
Acetylene C ₂ H ₂	< 0.1	% vol.
Higher-value HC (> C ₅ H ₁₂)	< 0.2	% vol.
CO	67.75	% vol.
N ₂	13.21	% vol.
CO ₂	16.22	% vol.
H ₂ O	2.52	% vol.
Trace substances and impurities	Value	Unit
H ₂ S	80	ppm
HF	7.1	mg/10 kWh
HCl	4.0	mg/10 kWh
Gas characteristics	Value	Unit
Lower calorific value	2.38	kWh/Nm ³

Hydrofluoric and hydrochloric acid

Step 1: calculation of the total quantity of chlorine

$$\text{Cl} [\text{mg}/10 \text{ kWh}] = \frac{\text{Chlorine molar mass}}{\text{HCl molar mass}} \times \text{Cl}' \quad \text{Cl} [\text{mg}/10 \text{ kWh}] = \frac{35.4}{36.4} \times 4 [10 \text{ mg}/\text{kWh}]$$

$$\text{Cl} = 3.9 [\text{mg}/10 \text{ kWh}]$$

Step 2: calculation of the total quantity of fluoride

$$\text{F} [\text{mg}/10 \text{ kWh}] = \frac{\text{Fluorine molar mass}}{\text{HF molar mass}} \times \text{F}' \quad \text{F} [\text{mg}/10 \text{ kWh}] = \frac{19}{20} \times 7.1 [10 \text{ mg}/\text{kWh}]$$

$$\text{F} = 6.7 [\text{mg}/10 \text{ kWh}]$$

Step 3: calculation of the total quantity of halogens

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$$\text{Hal} [\text{mg}/10 \text{ kWh}] \text{ CI} + 2 \times \text{F}$$

$$=$$

$$\text{Hal} [\text{mg}/10 \text{ kWh}] 3.9 [\text{mg}/10 \text{ kWh}] + 2 \times 6.7 [\text{mg}/10 \text{ kWh}]$$

$$=$$

$$\text{Hal} = 17.3 [\text{mg}/10 \text{ kWh}]$$

Step 4: comparison of actual and setpoint value

Without catalytic converter → Hal_L = 100 mg/10 kWh

Hal < Hal_L → OK

In principle, these sample calculations apply to all limit values indicated in mg/10 kWh.

Sample calculation of silicon operational value Si_o

Determined using two oil analyses:

Δ Si_{content in engine oil}: the increase of the Si content in the engine oil in ppm between two analyses, and

Δ oil service life: the operating time in hours between the two oil analyses.

$$\text{Si}_{\text{operational value}} [\text{Si}_O] = \frac{\Delta \text{Si}_{\text{content in engine oil}} [\text{ppm}] \times \text{total operating oil volume (l)}}{\text{Average engine power output [kW]} \times \Delta \text{oil service life (h)}} \times 1.1$$

The total operating oil volume equals the oil volume in the oil pan plus the oil volume of any additional oil tanks, if installed.

Refilling volume is definitely excluded.

Sample calculation

Increase in the Si content of the engine oil between two oil samples	40 ppm
Total operating oil volume	500 l
Engine power output	2000 kW
Operational oil life between the analyses	600 h

$$\text{Si}_o = \frac{40 \text{ ppm} \times 500 \text{ l}}{2000 \text{ kW} \times 600 \text{ h}} \times 1.1$$

Si_o=0.018 actual value

Si_{oL}=0.02 Si_o < Si_{oL} ⇒ OK

7 Revision code

Revision history

Index	Date	Description / Revision summary	Expert Auditor
9	30.04.2019	GE durch INNIO ersetzt / GE replaced by INNIO	Opoku

(10/10)

Revision history

			<i>Pichler R.</i>
8	30.11.2015	Ergänzung „Klassifizierung – Potenzieller Kunde“ / Additional „Classification - Prospective Customers“	Bilek Kelly
		Geringfügige Änderungen (Formatierung, Terminologie, Übersetzung)/ Minor Changes (formatting, terminology, translation)	Provin Nübling
		Ergänzung Verbrennungsluft und Gemisch / Extension for intake air and mixture	Provin Nübling, Wall
7	30.04.2015	Implementierung TA 1000-0301, TA 1000-0302, TA 1400-0091 und Umbenennung Treibgasanforderungen/ Implementation TA 1000-0301, TA 1000-0302, TA 1400-0091 and renaming Fuel gas requirements	Provin Nübling, Wall
6	06.11.2014	Hinweis zur Einhaltung der Bedingungen / Information on observing the conditions	Bilek Lippert
5	06.12.2013	Verbesserte Erläuterung der Ölfüllmenge / Improved explanation of the oil capacity	Kecht Wall