Lausleg athugun á nokkrum atriðum varðandi notkun á metangasi sem eldsneyti fyrir framdrifsvélar dagróðrabáta

Navis ehf.
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Inngangur.

Fyrir nokkru fékk Metan ehf. styrk frá Orkusjóði til að athuga hvort hagkvæmt geti verið að nota metangas sem eldsneyti til að knýja dagróðrabáta á Íslandi.

Taldi Metan ehf. heppilegast að fá ráðgjafa á skipatæknisviði til að kanna nánar nokkur af þeim atriðum sem verkefnið varða og óskaði eftir því að Navis ehf. veitti þá aðstoð.

Í greinargerð með styrkumsókn Metan ehf. var gert ráð fyrir að ef tilraun til metannotkunar í dagróðrabát yrði að raunveruleika, yrði raunhæfast að gera þá tilraun með því að breyta heppilegri núverandi dieselvél til metannotkunar, nánar tiltekið til brennslu á blöndu af metangasi og dieselolíu.

Þau atriði sem Navis ehf. var falið að vinna í þessu sambandi voru eftirfarandi:

- Að finna dagróðrabát með heppilegri vél sem hægt er að breyta með umræddum hætti.
- Að kanna möguleika á að koma metanorkubrigðum sem samsvara 50 lítrum eða meira af dieselolíu fyrir í bátnum.
- Gera kostnaðaráætlun fyrir slíkar breytingar og hagkvæmniútreikninga.

Eins og gengur og gerist komu upp ýmis atriði við nánari athugun sem breyttu fyrir huguðum framgangi verkefnisins en hér á eftir verður gerð lausleg grein fyrir helstu niðurstöðum þeirra athugana sem gerðar voru.

Nokkur atriði um notkun á metangasi sem eldsneyti á stimpilvélar.

Metangas kveikir ekki í sér sjálft við venjulegan þjöppunarþrýsting í stimpilvélum og þarf því utanaðkomandi aðstoð við að koma bruna af stað. Í sérsmíðuðum gasvélum er algengt að nota glóðarkerti líkt og í bensínvélum til að hrinda brunanum af stað og ganga slíkar vélar þá alfarið á gasinu.

Í dieselvélum er sá möguleiki hinsvegar fyrir hendi að nota dieseleldsneytiskerfið sjálft í sama tilgangi og áðurnefnd glóðarkerti. Metangasinu er þá blandað saman við loft í soggrein vélarinnar en tilsvarandi minnkuðu magni af dieseleldsneyti spýtt inn í strokkinn til að koma brunanum af stað.

Þetta fyrirkomulag hefur verið nefnt "dual-fuel" fyrirkomulag og getur hlutfall gassins verið á bilinu 15% til 85% af heildar eldsneytisnotkuninni eða jafnvel hærra.

Fyrir utan peningalegan sparnað sem getur hlotist af brennslu metans í stað dieselolíu má nefna ýmsan ábata vegna hreinni bruna og minni myndun mengunarefna og gróðurhúsalofttegunda við bruna metans sem leiðir af sér betri endingu véla og minni umhverfismengun.

Í grundvallaratriðum getur verið einfalt að breyta dieselvél fyrir dual-fuel fyrirkomulag og fáanlegur er ýmiss búnaður til slíkra breytinga, bæði einfaldur og flókinn, allt eftir tegundum véla og því hvert fyrirhugað hlutfall gass er í brennslunni.

Þegar þetta er skrifað er metangas hérlendis einungis fáanlegt samanþjappað á háþrýstigeymum undir þrýstingi allt að 220bar. Þannig er algengast að það sé notað í farartækjum á landi og þegar er eitthvað um að hér hafi bifreiðum verið breytt til dual-fuel notkunar með þessu gasi.

Í þessu ástandi er metan tiltölulega fyrirferðarmikið miðað við orkuinnihald, eða allt að 4.5 sinnum fyrirferðarmeira en t.d. dieselolía með sama orkuinnihald. Enskt tækniheiti fyrir þetta eldsneyti er CNG eða compressed natural gas.

Í nágrannalöndunum er þegar farið að nota metangas á minni skip en það er þá kælt og á fljótandi formi undir tiltölulega lágum þrýstingi, venjulegast undir 10 bar. Enskt tækniheiti þessa eldsneytis er LNG eða liquified natural gas. LNG tekur einungis um það bil sjötta part af því plássi sem CNG tekur, ef miðað er við orkuinnihald, og er því augljóslega miklu hagkvæmara til notkunar um borð í skipum þar sem pláss er oftast nær af skornum skammti.

Búnaður til breytinga á dieselvélum til dual-fuel fyrirkomulags og kostnaður hans.

Í seinni tíð hefur opnast nokkur markaður fyrir búnað til breytinga á dieselvélum sem fyrir eru í farartækjum á landi og í iðnaðarrekstri til dual-fuel fyrirkomulags og eru ýmsar útfærslur af búnaði til slíkra breytinga fáanlegar frá nokkrum framleiðendum.

Búnaður sá sem í boði er, er misflókinn/vandaður að gerð en samanstendur í aðalatriðum af þrýstingsstillingarbúnaði, lokabúnaði og í sumum tilvikum electroniskum gangráðum og tölvustýringum til að stilla hlutfall gasblöndunnar og stýra brunanum með sem hagstæðustum hætti.

Hinar fullkomnari gerðir þessa búnaðar miðast við stærri dieselvélar notaðar í iðnrekstri og í skipum en hinar einfaldari eru frekar stílaðar inn á breytingar á bílvélum.

Þeir bátar sem hér eru til skoðunar eru í aðalatriðum hraðskreiðir plastbátar ca. 11 – 15 metrar að lengd, búnir hraðgengum dieselvélum á bilinu 250 – 500 hestöfl við 1800 snúninga/mín. Á þessu stigi verður ekkert sagt um það hvaða búnaður getur dugað til breytinga á þessum vélum, en lauslegar kannanir hafa verið gerðar á líklegu verði búnaðar af sitt hvorum enda verðskalans.

Til að kanna verð á búnaði af vandaðri gerð var haft samband við svissneskt fyrirtæki, Huegli Tech AG sem hefur þróað búnað af þessu tagi. Bréfaskipti við það fyrirtæki fylgja með þessu skjali sem Fylgiskjal nr. I. Tæknilega útfærslu búnaðarins og frekari upplýsingar um hann má finna í Fylgiskjali nr. II.

Í stuttu máli þá er niðurstaða Huegli sú að frambærilegur búnaður til breytinga á dieselvél af því tagi sem hér er gengið útfrá muni kosta u.þ.b. EUR 9.820 eða ca. ÍSK 1.620.000. Til viðbótar þessum kostnaði yrði að gera ráð fyrir gashylkjum, en kostnaður þeirra hefur verið áætlaður USD 4000 eða um ÍSK 450.000. Erfitt er á þessi stigi að áætla kostnað við framkvæmd breytinganna, en lauslega má áætla hann á bilinu ÍSK 750.000 – 1.500.000. Heildarkostnaðurinn við breytingar með þessum búnaði gæti því verið á bilinu ÍSK 2.800.000 – 3.500.000.

Á hinum endanum á verðskalanum, þá er hægt að fá miklu einfaldari búnað sem seldur er til breytinga á dieselvélum í bílum (DIEL). Ekki reyndist unnt að fá ítarlegar upplýsingar um þennan búnað en út frá upplýsingum sem finna má á veraldarvefnum má ætla að búnaður og gashylki geti kostað allt að ÍSK 1.000.000 hingað komið. Á sömu forsendum og áður má því giska á að heildarkostnaður við breytingar á vél og bát geti verið á bilinu ÍSK 1.750.000 – 2.500.000.

Þess ber að geta að þessum búnaði fylgja engar electroniskar stýringar og sumt af búnaðinum fengi hugsanlega ekki viðurkenningu til notkunar í skipum.

Hagkvæmni metanbrennslu í fiskibátum.

Þegar athugunin var gerð var verð á dieselolíu til smábáta ÍSK 146/lítra. Þá var verð á metangasi ÍSK 120/Nm^3 frá Metan ehf. Orkuinnihald metangass á hvern Nm3 samsvarar 0.98 lítrum af dieselolíu þannig að á hverja orkueiningu kostar metangasið um 83.9% af því sem dieselolían kostar. Í reynd væri við hagstæðustu skilyrði verið að brenna blöndu af 10% dieselolíu og 90% metangasi. Miðað við að orkunýtingarhlutfall metangass í dieselvél sé það sama og dieselolíunnar væri því verð blöndunnar að meðaltali 85.51% af verði dieselolíu með sama orkuinnihald. Hugsanlegt er að orkunýting með metangasi sé eitthvað betri en með dieselolíu, en á þessu stigi verður ekkert fullyrt um það.

Ef við gerum ráð fyrir að dagróðrabátur af þeirri gerð sem hér er gengið út frá noti sem svarar 50 lítrum af dieselolíu í róðri og róðrafjöldi á ári sé um 100, þá kostar heildarolíunotkunin ÍSK 730.000. Miðað við að nota metangas að eins miklu leyti og mögulegt væri myndi því geta sparast 14.49% af þessari upphæð eða sem nemur tæplega ÍSK 106.000 á hverju ári í bein fjárútlát til eldsneytiskaupa.

Með einfaldasta hætti mætti því gera ráð fyrir að "endurgreiðslutími" fjárfestingarinnar ef ekki er tekið tillit til vaxta og þesshátttar gæti verið á bilinu 17 – 35 ár gróft reiknað.

Því virðist ljóst að miðað við verðlagningu á dieselolíu til fiskiskipa á Íslandi í dag, verður ekki um beinan fjárhagslegan ávinning fyrir sjálfan notandann að ræða við að breyta úr dieselolíu yfir í metannotkun í fiskibátum. Efnahagslegur ávinningur lægi því fyrst og fremst í þjóðhagslegum sparnaði vegna minni losunar gróðurhúsalofttegunda og mengunarefna og í gjaldeyrissparnaði vegna innfluttra orkugjafa. Að hinu leytinu gæti legið peningalegur sparnaður fyrir útgerðina í minna sliti á vél, minni viðhaldskostnaði og betri endingu.

Lög og reglur varðandi gasknúin skip og búnað þeirra.

Allur búnaður vinnu- og fiskiskipa á Íslandi er háður eftirliti og samþykki Siglingastofnunar Íslands og/eða viðurkenndra alþjóðlegra flokkunarfélaga og öll fljótandi för yfir 6 metra heildarlengd verða að uppfylla öryggiskröfur Siglingastofnunar til að hljóta haffærniskírteini.

Nauðsynleg forsenda haffæris fyrir metanbreyttan dagróðrabát væri því að breytingarnar fullnægðu gildandi kröfum til gasknúinna skipa. Hluti af athugun Navis ehf. fólst þessvegna í að kynna sér örlítið núverandi stöðu þessara mála að því er varðaði smábáta.

Fyrir liggja reglur nokkurra alþjóðlega starfandi og viðurkenndra flokkunarfélaga um gerð og frágang gasbúnaðar í skipum. Þessar reglur eru allar að miklu leyti samhljóða og byggjast á ályktun Alþjóðasiglingastofnunarinnar IMO RESOLUTION MSC.285(86). Þær reglur eiga það einnig sammerkt að þær miðast við stærri skip, þó nýleg dæmi séu um að skip allt niður í 25 metra lengd hafi verið búin til LNG driftar á grundvelli þessara reglna.

Smábátar undir 15 metra lengd og búnaður þeirra lúta hér á landi samnorrænum reglum (Nordic boat standard) sem gerðar voru í samvinnu milli siglingastofnana norðurlandanna og flokkunarfélagsins Det Norske Veritas. Í þessum reglum er hvergi gert ráð fyrir gasknúnum vélum til framdriftar og ekki er heldur kveðið á um annan gasbúnað um borð í þeim skipum heldur en þann sem notast ætti til eldunar og upphitunar.

Haft var samband við Siglingastofnun Íslands um málið og staðfesti Árni Friðriksson starfsmaður stofnunarinnar að ekki væru í gildi hér á landi neinar sérstakar reglur varðandi frágang gasbúnaðar á framdrifsvélar í bátum af þessari stærð. Stofnunin myndi því eiga erfitt með að taka út eða viðurkenna búnað af þessu tagi nema þá á grundvelli reglna flokkunarfélaganna eða ályktunar IMO.

Með milligöngu Árna Friðrikssonar var haft óformlegt samband við Siglingayfirvöld í Svíþjóð um málið og svöruðu þau hinu sama til, þ.e. að reglur um gasnotkun til framdriftar í bátum undir 15m lengd væru ekki til og að ef þörf virtist vera fyrir slíkar reglur í framtíðinni yrðu þær væntanlega gerðar á grundvelli ályktunar IMO og yrðu vafalaust ein 2-3 ár í smíðum.

Samskonar fyrirspurn til norskra siglingayfirvalda leiddi af sér mun einfaldara svar, þ.e. að samkvæmt samnorrænum reglum um smíði báta undir 15 metrum væru vélar aðrar en dieselvélar ekki leyfðar í bátum yfir 6m lengd og gasdrift kæmi því ekki til greina í bátum af þessari stærð miðað við núgildandi regluumhverfi.

Að fengnum þessum svörum er því fróðlegt að skoða nokkur af helstu atriðum IMO ályktunar MSC.285(86) er myndu varða CNG kerfi í smábátum. Nokkur dæmi um þær kröfur sem varða staðsetningu og fyrirkomulag gasbúnaðar í skipum eru eftirfarandi:

- Öll gasrör skulu hafa tvöfaldan vegg eða liggja í gasþéttum stokkum þar sem millirými er fyllt af óvirku gasi. Ef upp kemur gasleki í kerfinu skal vera völ á öðru eldsneyti til framdriftar.
- Gasþrýstingur í lögnum eða geymum undir þilfari skal ekki vera meiri en 10 bar. Þetta þýðir að í CNG kerfum þurfa gasgeymar og þrýstiminnkarar að vera staðsettir ofan þilfars.
- Gasgeyma skal staðsetja eins nálægt miðlínu skips eins og kostur er og ekki nær skipshlið en 0.76m. Sama máli gegnir um gaslagnir. Gaslagnir skulu þannig lagðar og frágengnar að þær verði ekki fyrir hnjaski.
- Gerðar eru kröfur um sérstaka loftræstingu vélarúma fyrir gasknúnar vélar samkvæmt nánari útlistun.

Ofangreind ályktun IMO fylgir með þessu skjali sem Fylgiskjal nr. III – fyrir þá sem vilja kynna sér málið nánar.

Fyrirkomulag og staðsetning búnaðar um borð í dagróðrabát.

Hvað varðar val á "heppilegum" bát til slíkra breytinga má segja að þar komi aðallega til álita vélargerðin; bátarnir sjálfir sem til greina koma eru nokkuð einsleitir að gerð, stærð og fyrirkomulagi.

Af gögnunum frá Huegli Tech er að skilja að þeir treysti búnaði sínum eingöngu í vélar með mekaníska gangráða.

Fyrirmæli Metan ehf. voru þau að kannað skyldi hvernig hægt væri að koma fyrir gasbirgðum sem samsvöruðu 50l af dieselolíu um borð í svona bát.

Gróflega reiknast til að hér yrði um að ræða rúmlega 200 lítra af gasi við 220 bar þrýsting.

Í Fylgiskjali nr. IV er sýnd fyrirkomulagsteikning af dæmigerðum dagróðrabát, hraðfiskibát, þar sem komið hefur verið fyrir tveimur gashylkjum 16" x 50" sem rúma ríflega það magn sem um var talað, og er þeim komið fyrir í samræmi við fyrirmæli IMO ályktunarinnar. Tveir möguleikar á staðsetningu eru sýndir, þ.e. annarsvegar liggjandi aftast á þilfarinu yfir vélarúmi, til að lagnir geti verið eins stuttar og mögulegt er og hinsvegar standandi aftan við afturþil stýrishúss, en þá eru lagnir miklu lengri og þyrftu að vera í hlífðarstokk ofan þilfars. Báðar staðsetningar hafa ókosti en virðast þær einu sem völ er á.

Niðurstöður.

Niðurstöður athugunarinnar eru tiltölulega einfaldar. Svo virðist sem gildandi regluumhverfi fyrir gerð og búnað fiskibáta af því tagi sem hér eru til umfjöllunar muni geta komið í veg fyrir að bátur með slíkan búnað fengi haffærisskírteini hér á landi í dag.

Að vísu er ekki hægt að útiloka að Siglingastofnun sýndi af sér þann velvilja að taka út dual-fuel kerfi er fullnægði kröfum IMO Resolution MSC.285(86), en allavega er nokkuð ljóst að talsverða forvinnu og tíma þyrfti til að hanna slíkt kerfi á grundvelli reglnanna og tryggja að búnaður sá sem keyptur yrði stæðist allar gildandi reglur.

Miðað við þær grófu forsendur sem gefnar hafa verið um stofnkostnað annarsvegar og eldsneytissparnað hinsvegar virðist ljóst að á grundvelli núverandi verðlagningar á dieselolíu til smábáta þá sé breyting til metannotkunar ekki peningalega hagkvæm.

Fylgiskjal nr. I

Dear Sirs,

We are a marine consultancy firm engaged in various design and consultative services to the fishing industry.

Recently, a supply of clean compressed landfill gas has become available in our locality and the supplier is interested in promoting the use of this gas for industrial purposes, especially for propulsion of small fishing vessels on the dual-fuel principle.

In the short term, the idea would be to convert an existing high speed marine diesel engine to dual-fuel operation with conventional diesel fuel and compressed landfill gas, on an experimental basis.

Most of the engines which come into consideration are high speed marine diesels of around 300kW and the most common makes are Cummins, Volvo Penta, Caterpillar and Yanmar, although other makes are in use also.

We are interested in assisting in the promotion of the initial developments in this direction here and are looking for a reliable supplier of the equipment which would be required for such a conversion.

We have seen from your downloadable literature that you have supplied conversion kits for a number of successful dual-fuel conversions of industrial high speed diesel engines and we would therefore be very interested in hearing whether you would be interested in supplying kits for conversion of marine engines.

In particular, we would be most obliged if you would be kind enough to enlighten us on the following:

- What would be the likely cost of a conversion "kit" for a 300kW Cummins engine, say, and what would such a "kit" comprise?
- Would you trust a highly experienced local diesel workshop with the installation and conversion work?
- If not, would your company be interested in providing a specialist to assist an experienced workshop in such a conversion and subsequent start-up and tuning and what would such assistance be likely to cost?

This idea is still in the exploratory stage, but we would nevertheless be very grateful if you would care to give us your ideas on the matter. Similarly we would be happy to answer any queries or questions you may have.

I look forward to hearing from you in the near future.

NAVIS ehf.

Karl Ludviksson

Dear Mr. Ludviksson,

Thank you for your very interesting e-mail. As you mention, our activities to date have centered around stationary applications but ship propulsion also tends to be steady-state for much of the time. Our system offers dynamic control of both fuels, allowing us to quickly adjust the mix to use as little diesel as possible in steady state (for economy) or to increase to almost 100% diesel (for a fast response) when increasing speed or dealing with an increased load.

I need to consult with my colleagues before we could make any proposals regarding the components required.

We are certainly interested in co-operating with you and perhaps a local yard to convert your proposed trial engine. Ingo Fisher is our gas and dual-fuel expert and he routinely travels all over the world, working with local companies to install and commission these systems.

I have 3 initial questions:

1. What are the current prices of the landfill gas and diesel in Iceland?

2. Do you have details about its max./min. methane content?

3. What are the typical annual running hours (or better still, diesel consumption) of an Icelandic fishing vessel?

Dual-fuel conversions are really about a pay-back period and subsequent savings and these answers will give us an idea how good a financial case we could make to the ship operators.

Please note that I have copied this e-mail to Technoflex, our agent in Denmark. They are responsible for component sales to Iceland and any goods, following a successful trial, would be supplied by them.

If you have any questions, please do not hesitate to contact me.

Best regards,

David Smith

Area Sales Manager

HUEGLI TECH SWITZERLAND

HUEGLI TECH AG [Ltd]

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4900 Langenthal

Switzerland

Dear Mr. Smith,

Many thanks for your swift answer to my query.

I apologize for taking so long to reply, but I have been busy with other things.

Before addressing your specific questions below, I have to explain that the type of vessel we would like to use for trials is a typical fast inshore boat, about 11 metres in length and fitted with a 300kW engine giving speeds up to 25 – 30 knots. These boats take very short time to reach the fishing grounds, where the engine operates at very low load or is shut down during fishing operations and each fishing trip is completed with a fast passage back to port. A typical boat of this kind will make on the average 100 such fishing trips per year.

The answers to your questions below are as follows:

1. The price of landfill methane here at the moment is approx. Eur. 0.72/Nm^3. The current price of diesel as sold to these boats is Eur. 0.92/litre. (The price to motorists is considerably higher than that)

2. The purified gas is said to be 97.525% methane (or better)

3. I would estimate the annual consumption of diesel to be 5000 – 7000 litres/year

Due to the relatively small annual consumption and the low price of diesel, the scope for savings is not very great. The economics of the operation do not play a big role at the moment, however, the environmental aspect is a bigger factor.

In any case, I look forward to hearing from you in the near future.

With best regards,

NAVIS ehf.

Karl Ludviksson

Dear Mr. Ludviksson,

I'm sorry to keep you waiting. We have been considering the most cost-effective components to offer. The costs will depend upon the engine layout and the governing system already fitted. As an example I have put together a **budgetary** quotation based upon an in-line 6 Cylinder Cummins engine with a mechanical governor:

	In-Line 6 Cyl		Qty	Quote (EUR)
1135	DFM-100	Dual Fuel Module	1	639.80
5664	ESD-5335-CE	Governor	1	356.65
1235	MSP-6728C	Pick-Up	1	52.85
5888	ADB-120-E4-HT-F	Actuator	1	800.45
1500	EC-1000	Connector	1	5.95
7785	ATB-552T2-F4-24	Throttle Body	1	591.15
4812	BK-115-E4-HT	Actuator Bracket	1	45.50
5667	CH-1209AB-L15	Wiring Harness for feedback	2	79.10
5818	DF-5-Mixer	Gas Mixer	1	486.15
3240	HAX-518	Hose adaptor	4	182.00
2153	SVX-591	Solenoid Shutdown Valve	1	799.75
1559	Denox-16-F	Anti knocking controller	1	2296.28
1558	0261 231 006	Anti knocking sensor	6	426.30
5648	CH-Denox-6-L10	Cable Harness for Denox	1	314.65
5642	T-2472-3000	Thermocouple	1	162.75
5825	TMC-2000-DF-Y3	Temp. Controller	1	860.00
7230	MSP-LEF-L85	Temp. Sensor	1	245.35
7424	CH-MSP-SIHTM-L7	Cable Harness for MSP	1	87.50
-	Gas Street	Gas Street	1	1390.00
		Total Equipment Price		**9822.18**

The material list includes an electronic governor and integral actuator to be fitted to the fuel pump, the unit that balances the two fuels, a throttle for the airflow and a mixer to ensure a controlled gas supply. These are the key components of the conversion and the rest can be considered as necessary ancillaries.

The Gas Street is a series of valves and filters to ensure that the gas that arrives at the mixer is clean and at nominally zero pressure. The make-up of the gas street varies from application to application; as it is critical to the proper functioning of the gas supply we source the components from a specialist Swiss manufacturer and we supply the assembled unit at cost. The EUR 1390.—in the table is from a stationary natural gas application and is likely to change for a bottled methane supply. We will probably need less filtering, but perhaps another pressure-reduction stage.

In order to make the most of the gaseous fuel, the engine needs to be run close the point of pre-ignition. The anti-knocking system ensures that this damaging condition is prevented. Likewise gas burns hotter than diesel and a temperature monitoring system is needed to prevent overheating.

The solenoid shutdown valve is a butterfly valve placed in the air inlet and designed to choke the engine in case of a runaway condition. We fit these valves to all engines fuelled with a gas.

The rest of the items are mainly sensors and wiring harnesses.

One critical component that is not included is a supervising control system. It will depend upon the individual vessel exactly what additional equipment is required.

One major factor that I did not mention before is that we cannot offer to convert modern electronic (ECU) engines to dual-fuel operation. Their ECU mapping is simply not designed to handle the addition of a second fuel.

As you can see the realistic equipment cost to convert a 300kW engine to handle the addition of the landfill methane is likely to be in the region of EUR 10K – 12K. As I mentioned before, for a large engine with a big difference in cost between diesel and gas, this level of conversion cost is negligible. In this particular application we are interested to see whether such a cost would be considered acceptable.

I look forward to your response with interest.

Best regards,

David Smith

Area Sales Manager

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4900 Langenthal

Switzerland

Fylgiskjal nr. II

HUEGLI TECH AG (LTD)
The Engine & Genset Control Company

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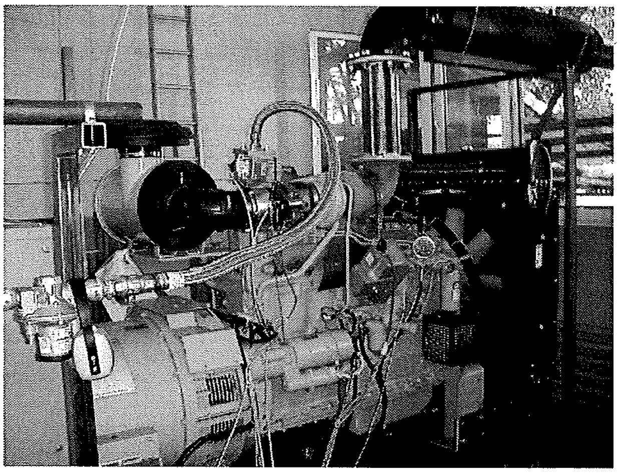
DUAL FUEL CONVERSION FOR HIGH SPEED ENGINE

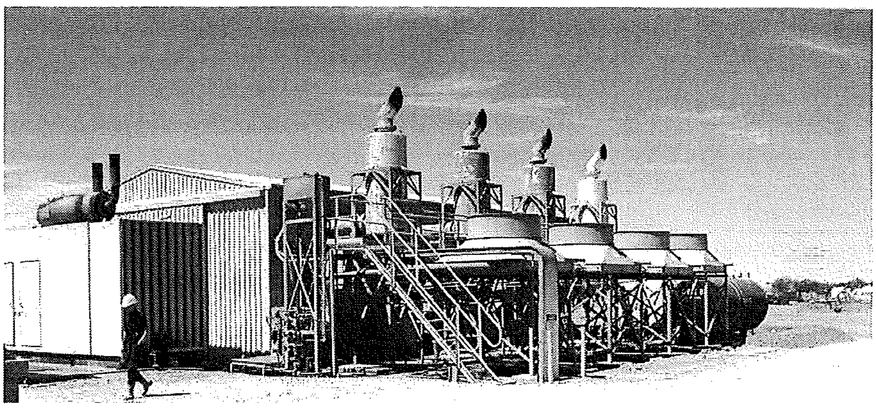
Huegli Tech LTD offers an innovative retrofit technology to convert your diesel engine systems to operate reliably and efficiently on Dual Fuel natural gas. We tailor each system to fit individual customer requirements.



Return of Investment: Less than 6 Months

This kit is a relatively low cost way to get your existing high speed engine running on dual fuel. Taking advantage of inexpensive natural gas as a primary fuel, you will also retain the ability to run your engine on full diesel without losing horsepower. Current replacement rate of diesel-to-gas is approximately 70% of the diesel fuel.

Kit includes: Mixer system with integrated gas metering valve, electronic control system, gas delivery system, additional diesel delivery components, air controls, gas plumbing and necessary operational documentation



HIGHLITS

- **Save Money with cheaper fuel**
- **Simple conversion is cost effective**
- **Low pressure Gas compatible**
- **100% power at diesel or dual fuel**

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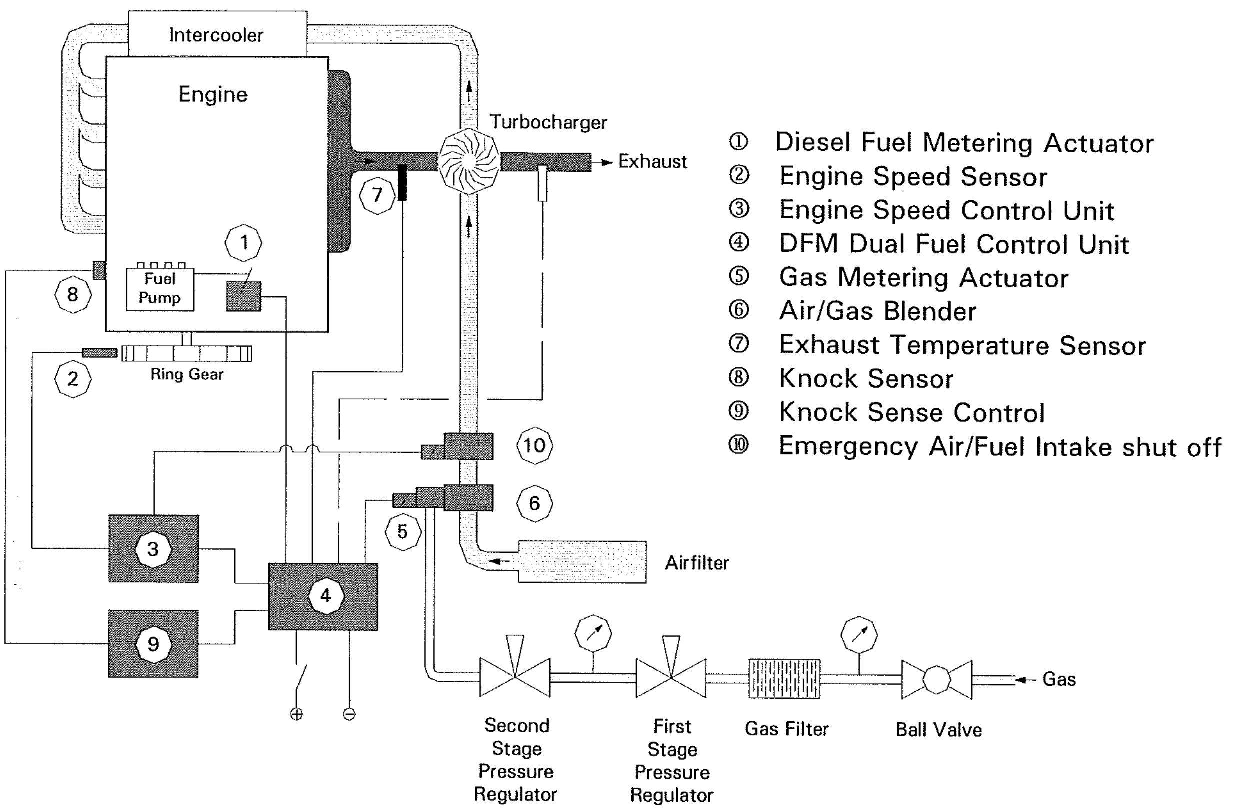
Block Diagram



Target

The target is to **safely operate** the engine at a diesel fuel/gas ratio of 30/70, or even better, and maintain the **same power output,** and the same **fast response time** as with 100% diesel fuel.

Operating Principle

The DFM Dual Fuel Control ④ sets the amount of injected diesel fuel via the actuator with position
sensor ①. The actuator is linked to the fuel pump. Via another actuator ⑤ the DFM control also regulates the amount of gas into the air/gas blender ⑥.The air air/gas mixture then passes through the turbo charger, through the intercooler into the engine. The requested engine speed is controlled by the governor control ③, which measures the engine speed at the engine ring gear via speed sensor②.Isochronous or droop mode is possible.

Dynamic Performance

The DFM has dynamic characteristics, i.e. during load steps it momentarily increases the amount of injected diesel fuel for shortest possible transients.

Protection and Safety

The system protects the engine against harmful situations.
The exhaust temperature is monitored via sensor ⑦. If the temperature should exceed the set (safe) Limit, the DFM control reduces the gas portion, and increases the diesel fuel portion.
The System also avoids harmful knocking. (Detonation)
One, or several knock sensors ⑧ signal any knocking tendency to the knock control ⑨, which then signals the DFM control ④ to change the gas/diesel fuel ratio to eliminate knocking.

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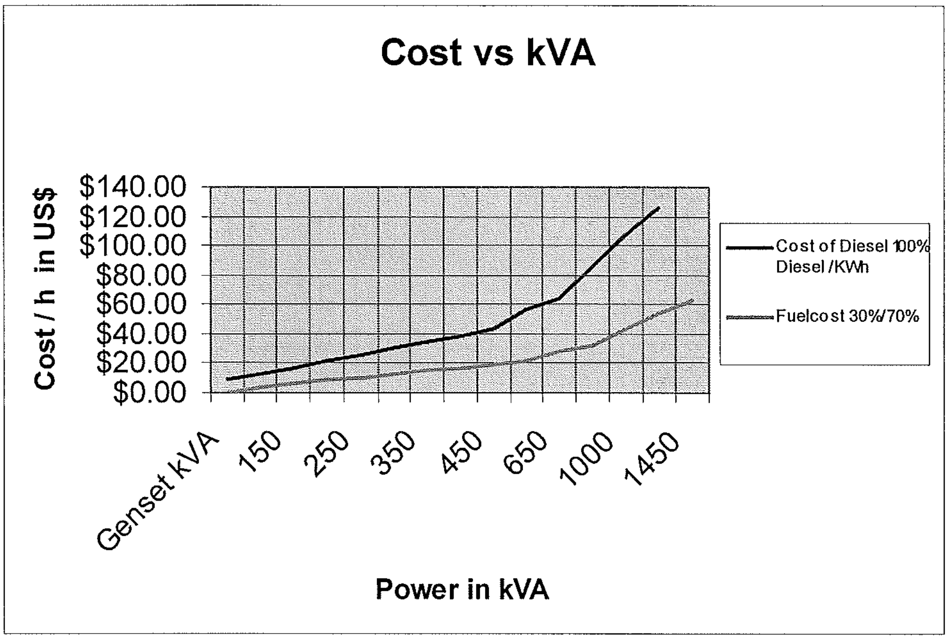
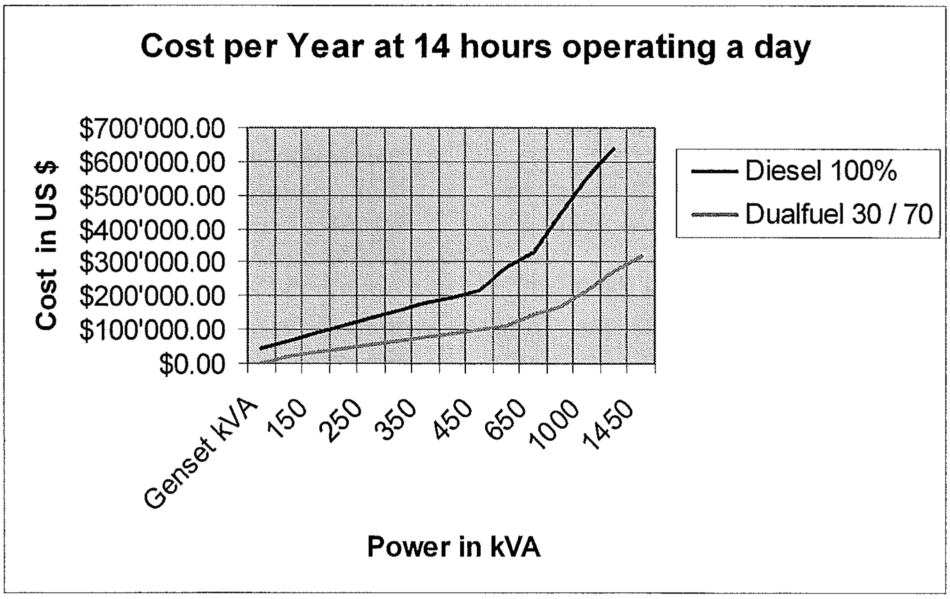
Cost comparison The comparison is based on Pakistan fuel and gas cost. An automatic calculation table is available in Excel which allows calculating with any fuel cost. Please contact us so we can provide more information to you.





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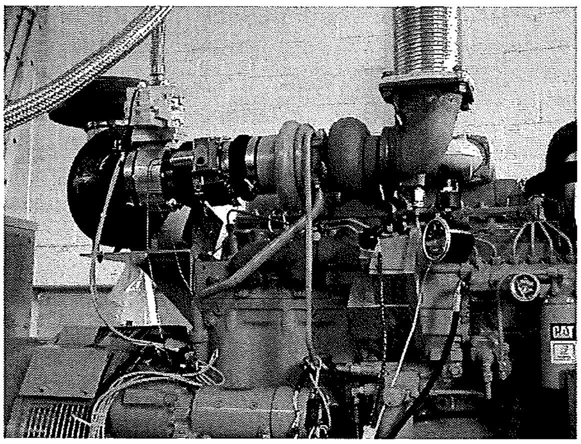
HUEGLI TECH LTD Huegli Tech LTD introduces its latest dual fuel conversion system DFM 100, for the industrial high speed four stroke diesel engine market. The DFM 100, a cost effective and affordable means of converting diesel engines into diesel-natural gas engines, allowing the use of cost effective natural gas without changing the entire engine.

The DFM 100 dual fuel system is designed to be installed on new or existing diesel engines without modifying any internal engine components. Installations of the components are straightforward, with only reasonable mechanical expertise required. Final tuning and testing is typically performed by a trained service technician or a representative. Dual fuel units also allow the user the flexibility to run dual natural gas with diesel or strait diesel, an extremely important consideration for applications with interrupted gas supply. Diesel operation remains unchanged. The DFM 100 is engineered so if a function falls out of normal operational limits, full Diesel operation is resumed instantly and seamlessly, with no interruption of service.

How to do it Installation of the kit usually takes a day or two. The kit is manufactured according to the dimensions given by the questionnaire returned to us and suits without additional modification. The site needs a gas supply line with at least 2 PSI of available gas pressure (higher pressures allows for smaller control devices and better stability of gas supply). Via Gas Street the supply is piped to the engine, close to the air inlet. The conversion system takes it from there to supply the diesel engine with a clean regulated gas supply that controls the fuel delivery to the engine and blends the fuel with the air. Sensors need to be fixed, to measure critical engine functions like speed, load, water temperature, exhaust temperature and gas pressure. Voltage for powering the control system is typically 24 volts DC. Mounting of the Diesel actuator to the fuel pump either integral or external solution without having special knowledge on fuel pumps. The gas actuator is already pre mounted to the Air / Gas Mixer. The mixer needs to be placed between the Air filter and Turbocharger. Wiring to connect the sensors to the Electronic Control Unit's.

To start up the first time, the DFM 100 can be adjusted in Diesel mode first, to avoid any engine damage.

! Easy, fast and qualified installation safes time and cost!



Quality While reducing equipment cost is an important goal, no short cuts are taken with respect to quality. Only top quality products are utilized in the conversion system. From the Main Controller to the pick up connector, all meets high SWISS standard at an affordable price!

Fuel Economy A DFM 100 conversion is a perfect investment for power users who are looking to upgrade their current system to alternative fuel technology, without revamping their entire system. As a retrofit technology, the DFM 100 system provides an economically attractive alternative instead of buying costly new generators.

With the ability to operate both fuels, the engine will never be down due to a lack of adequate gas fuel supply. Another distinct advantage of dual fuel is the decreased engine wear that comes with the use of cleaner fuel. Due to a reduction of carbon soot build-up and cleaner lube oil, longer intervals between service maintenance can be expected, sometimes doubled. This means a longer economic life for the engine and a better overall return on your investment.

Savings To determine approximate cost savings you will need to be aware of your present fuel cost. The fuel replacement percentage and replacement cost with natural gas is in the ration of approx: 30 / 70, but also can be lower. Be sure to apply any losses of efficiency and always estimate on the safe side. Ask a Huegli Tech representative to help you in determining your annual cost savings including fuel and maintenance.

When considering the cost of natural gas also consider your contract options with your gas supplier. Many suppliers are willing to give better rates if they are able to interrupt your fuel supply. An interruptible rate is exactly why the Dual Fuel system is a desirable option.

! Uninterrupted power supply around the clock safes cost for production and investment!

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Safety Features Combustion knock is where the air fuel mix in the combustion chamber starts to auto-ignite from the increasing pressures and high temperatures. It causes high pressure spikes and can cause engine damage. Knock is the reason many engines can not run full power at a minimized pilot fuel setting. Each engine family has its own differences and characteristics. Different fuel timing, compression ratio and Turbocharger configurations affecting air fuel ratio, boost pressures and temperatures. The ambient temperature affects the combustion and so does the content of the gas. All of these factors come into play and make it somewhat difficult to predict exactly what power limit will be reached with minimized pilot fuel and what amount of pilot fuel will be required at full power. The DFM 100 system is designed to replace as much diesel fuel as is possible without running into the combustion knock limit. To accomplish this, the controller has an additional input and communicates with a Ant knocking system which listens to the engine via high sensitive vibration piezo sensors. This allows reducing diesel as close to the knocking threshold as possible without endangering the engine at any time.

High exhaust temperature is monitored constantly via Thermocouple Sensor. An adjustable set point on the DFM 100 for high temperature will reduce the gas and increase diesel fuel to prevent the engine from damage. The DFM 100 will continuously govern along the knocking threshold if necessary. This feature helps to increase efficiency on CHP applications.

With an additional multifunctional genset controller, IntelliSys, each cylinder temperature can be monitored. IntelliSys is capable to reduce either the generator power or change the mode of the DFM 100 to single fuel operation.

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Scope of Supply

Electronic's :

- **DFM-100 Dual Fuel Controller**
  The DFM 100 is capable of controlling 2 actuators independently at the same time. It is possible to freeze one actuator to an adjustable value.

- **ESD-5330 Speed Governor High Performance**
  The ESD 5330 is a speed governor with enhanced features which allows controlling any dynamic situation of a combustion engine.

- **IG-CU or IS-CU Genset Controller ***
  IG-CU or IS-CU are enhanced gen-set automation controllers with engine protection features.
- **Denox-2DF Antiknocking Control ***
  Denox detects the engine knocking via knocking sensors.

Actuators:

- **ACE-XXXF-24 Diesel Actuator**
  To control the Diesel fuel proportionally either an integral type or external actuator is mounted to the fuel pump.
- **ATB-XXXF-24 Gas Valve Actuator**
  This is an Integrated Butterfly actuator which controls the Gas fuel proportionally

Sensors:

- **MSP-6728C Magnetic Pick Up**
  Magnetic Speed sensor to measure the engine speed.
- **Exhaust Temperature Sensor**
  K-Type thermocouple to measure the exhaust temperature
- Knocking Sensor *

Air Gas MiXer:

- ! This device is selected according the questionnaire which has to be completed !

Gas Components:

- Gas Filter *
- Pressure Regulator *
- Manual Valves *
- Electric Valves *
- Pressure Switch *

*Indicates Optional Device.

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Selection Table for variouse engines

Engine	Remarks	Diesel Actuator	Gas Actuator	Speed Pick Up
Cummins				
NT 855	PT Pump System	ADB 120 E4 HTF	ATB 350F-24	MSP 6728C
NTA 855	PT Pump System	ADB 120 E4 HTF	ATB 350F-24	MSP 6728C
KT/KTA Series	PT Pump System	ADB 120 E4 HTF	ATB 450F-24	MSP 6728C
Caterpillar				
3306		ACD 295F-24	ATB 350F-24	MSP 6728C
3512		ACB 2001F	ATB 550F-24	MSP 6728C
3516		ACB 2001F	ATB 550F-24	MSP 6728C
Deutz				
913		ACD 175 F-24	ATB 350F-24	MSP 6728C
1015		ACE 275 F-24	ATB 350F-24	MSP 6728C
1012/13		ADD 180GF-24	ATB 350F-24	MSP 6728C
MAN				
2842		ACE-275F-24	ATB 350F-24	MSP 6728C
2866		ACE-275F-24	ATB-350F-24	MSP6728C
Dewoo				
TD 229		ACD 175 F-24	ATB 350F-24	MSP 6728C

Selection Table for Perkins engines

Engine	Diesel Actuator	Gas Actuator	Mounting Kit	Pick-up
1306 (TAG)	ACD -175F-24	ATB 350F- 24	KT 275-3000	MSP 6728C
2006 (TA)	ACE 275F-24	ATB 350F -24	KT 275-3000	MSP 6728C
3008 (TA)	ACE 275F-24	ATB 450F -24	KT 275-3000	MSP 6728C
3012 (TWA)	ADD 225F or ACE 275F	ATB 450F -24	KT 225/3012C (M10) or KT225/3012D (M8) Kit on request	MSP 6728C
4000...TAG Dorman range)	ACB 2001F	ATB 550F -24	Kit on request	MSP 6728C

Selection Table for Volvo engines

Engine	Bosch fuel pump	Diesel Actuator	Gas Actuator	Mounting Kit
TD 420, TAD 420	Stack Pump's	ADD 225F-S-24	ATB 350F-24	CH 1208AM-L3
TD 520, TAD 520		ADD 180GF-24	ATB 350F-24	KT 1213 B
TD 720, TAD 720			ATB 350F-24	CH 1220-L3
TD 610, TWD 610	MW	ACD 175F-24	ATB 350F-24	KT-166
TD 710, TWD 710	if P 3000	ACD 175F-24	ATB 350F-24	KT 275-3000
	if P 7000	ACD 175F-24	ATB 350F-24	KT 276-7000
TAD 721 TAD 730 TAD 740 TAD 741	if P 3000	ACD 175F-24	ATB 350F-24 ATB 350F-24	KT 275-3000
	if P 7000	ACD 175F-24	ATB 350F-24 ATB 350F-24	KT 276-7000
TD 1010	if P 3000 if P 7000	ACD 175F-24	ATB 350F-24	KT 275-3000 KT 276-7000
TAD 1030 TAD 1031 TAD 1032	P 7000	ACD 175F-24	ATB 450F-24	KT 276-7000
TWD 1211 TAD 1231	if P 3000 if P 7000	ACD 175F-24 ACD 175F-24	ATB 450F-24	KT 275-3000 KT 276-7000
TAD 1230	P 7000	ACD 175F-24	ATB 450F-24	KT 276-7000
TAD 1232 TAD 1240 TAD 1241 TAD 1242	**Up on request**			
TAD 1630	P 7000	ACE 275F-24	ATB 550F-24	KT 276-7000
TAD 1631 TAD 1632 TAD 1633	RP 21	ACE 275F-24	ATB 550F-24	KT 1611

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Fylgiskjal nr. III

ANNEX 11

RESOLUTION MSC.285(86)
(adopted on 1 June 2009)

INTERIM GUIDELINES ON SAFETY FOR NATURAL GAS-FUELLED ENGINE INSTALLATIONS IN SHIPS

THE MARITIME SAFETY COMMITTEE,

RECALLING Article 28(b) of the Convention on the International Organization concerning the functions of the Committee,

NOTING that the International Convention for the Safety of Life at Sea, 1974 currently does not have any provisions for use of gas as fuel on ships other than gas carriers,

RECOGNIZING a need for the development of a code for gas-fuelled ships,

ACKNOWLEDGING that, in the interim, there is an urgent need to provide guidance to the Administrations on the gas-fuelled engine installations in ships,

HAVING CONSIDERED the Interim Guidelines prepared by the Sub-Committee on Bulk Liquids and Gases at its thirteenth session,

1. ADOPTS the Interim Guidelines on safety for natural gas-fuelled engine installations in ships, the text of which is set out in the Annex to the present resolution;

2. INVITES Governments to apply the Interim Guidelines to gas-fuelled ships other than those covered by the IGC Code;

3. URGES Member Governments and the industry to submit information, observations, comments and recommendations based on the practical experience gained through the application of these Interim Guidelines and submit relevant safety analysis on gas-fuelled installations;

4. AGREES to continue the work on the development of the International Code of Safety for Gas-fuelled Ships (IGF Code).

ANNEX

INTERIM GUIDELINES ON SAFETY FOR NATURAL GAS-FUELLED ENGINE INSTALLATIONS IN SHIPS

Index

PREAMBLE

1 These Interim Guidelines have been developed to provide an international standard for ships, other than vessels covered by the IGC Code, with natural gas-fuelled engine installations.

2 The goal of these Interim Guidelines is to provide criteria for the arrangement and installation of machinery for propulsion and auxiliary purposes, using natural gas as fuel, which will have an equivalent level of integrity in terms of safety, reliability and dependability as that which can be achieved with a new and comparable conventional oil-fuelled main and auxiliary machinery.

3 To achieve this goal, the functional requirements described below are embodied in the relevant parts of these Interim Guidelines:

.1 Minimize hazardous areas as far as is practicable to reduce the potential risks that might affect the safety of the ship, personnel and equipment.

.2 Minimize equipment installed in hazardous areas to that required for operational purposes. Equipment installed in hazardous areas should be suitable and appropriately certified.

.3 Arrange hazardous areas to ensure pockets of gas cannot accumulate under normal and foreseeable failure conditions.

.4 Arrange propulsion and electrical power generating installation to be capable of sustained or restored operation in the event that a gas-fuelled essential service becomes inoperative.

.5 Provide ventilation to protect personnel from an oxygen deficient atmosphere in the event of a gas leakage.

.6 Minimize the number of ignition sources in hazardous spaces by design, arrangements and selection of suitable equipment.

.7 Arrange safe and suitable gas fuel storage and bunkering arrangements capable of taking on board and containing the gas fuel in the required state without leakage and overpressure.

.8 Provide gas piping systems, containment and overpressure relief arrangements that are of suitable design, construction and installation for their intended application.

.9 Design, construct, install, operate and protect gas-fuelled machinery, gas system and components to achieve safe and reliable operation consistent with that of oil-fuelled machinery.

.10 Arrange and locate gas storage tank rooms and machinery spaces such that a fire or explosion in either will not render the machinery/equipment in other compartments inoperable.

.11 Provide safe and reliable gas-fuel control engineering arrangements consistent with those of oil-fuelled machinery.

.12 Provide appropriate selection of certified equipment and materials that are suitable for use within gas systems.

.13 Provide gas detection systems suitable for the space concerned together with monitoring, alarm and shutdown arrangements.

.14 Provide protection against the potential effects of a gas-fuel explosion.

.15 Prevent explosion and hazardous consequences.

.16 Provide fire detection, protection and extinction measures appropriate to the hazards concerned.

.17 Provide a level of confidence in a gas-fuelled unit that is equivalent to that for an oil-fuelled unit.

.18 Ensure that commissioning, trials and maintenance of gas utilization machinery satisfy the goal in terms of reliability, availability and safety.

.19 Provide provision for procedures detailing the guidelines for safe routine and unscheduled inspection and maintenance.

.20 Provide operational safety through appropriate training and certification of crew.

.21 Provide for submission of technical documentation in order to permit an assessment of the compliance of the system and its components with the applicable rules and guidelines.

4 The Interim Guidelines address the safety of ships utilizing natural gas as fuel.

5 Natural gas (dry) is defined as gas without condensation at common operating pressures and temperatures where the predominant component is methane with some ethane and small amounts of heavier hydrocarbons (mainly propane and butane).

6 The gas composition can vary depending on the source of natural gas and the processing of the gas. Typical composition in volume (%):

Methane (C_1)	94.0%
Ethane (C_2)	4.7%
Propane (C_3)	0.8%
Butane (C_4+)	0.2%
Nitrogen	0.3%
Density gas	0.73 kg/sm^3
Density liquid	0.45 kg/dm^3
Calorific value (low)	49.5 MJ/kg
Methane number	83

The gas may be stored and distributed as compressed natural gas (CNG) or liquefied natural gas (LNG).

CHAPTER 1

GENERAL

1.1 Application

1.1.1 These Interim Guidelines apply to internal combustion engine installations in ships using natural gas as fuel. The engines may use either a single fuel (gas) or dual fuel (gas and oil fuel), and the gas may be stored in gaseous or liquid state.

1.1.2 These Interim Guidelines should be applied in addition to the relevant provisions of the International Convention for the Safety of Life at Sea (SOLAS), 1974 and the Protocol of 1988 relating thereto, as amended.

1.1.3 The Interim Guidelines are applicable to new ships. Application to existing ships should be decided by the Administration to the extent it deems necessary.

1.2 Hazards

These Guidelines address the hazards related to the arrangements for the storage, distribution and use of natural gas as a fuel.

1.3 Definitions

For the purpose of these Guidelines, unless otherwise stated below, definitions are as defined in SOLAS chapter II-2.

1.3.1 *Accidents* mean uncontrolled events that may entail the loss of human life, personal injuries, environmental damage or the loss of assets and financial interests.

1.3.2 *Certified safe type* means electrical equipment that is certified safe by a recognized body based on a recognized standard[1]. The certification of electrical equipment is to correspond to the category and group for methane gas.

1.3.3 *CNG* means compressed natural gas.

1.3.4 *Control stations* mean those spaces defined in SOLAS chapter II-2 and additionally for these Guidelines, the engine control room.

1.3.5 *Double block and bleed valve* means a set of three automatic valves located at the fuel supply to each of the gas engines.

1.3.6 *Dual fuel engines* mean engines that can burn natural gas and fuel oil oil fuel simultaneously or operate on oil fuel or gas only.

1.3.7 *Enclosed space* means any space within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally[2].

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[1] Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features.

[2] See also definition in IEC 60092-502:1999.

1.3.8 *ESD* means emergency shutdown.

1.3.9 *Explosion* means a deflagration event of uncontrolled combustion.

1.3.10 *Explosion pressure relief* means measures provided to prevent the explosion pressure in a container or an enclosed space exceeding the maximum overpressure the container or space is designed for, by releasing the overpressure through designated openings.

1.3.11 *Gas* means a fluid having a vapour pressure exceeding 2.8 bar absolute at a temperature of 37.8°C.

1.3.12 *Hazardous area* means an area in which an explosive gas atmosphere or a flammable gas (flashpoint below 60°C) is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

Hazardous areas are divided into zones 0, 1 and 2 as defined below[3]:

.1 *Zone 0* is an area in which an explosive gas atmosphere or a flammable gas with a flashpoint below 60°C is present continuously or is present for long periods.

.2 *Zone 1* is an area in which an explosive gas atmosphere or a flammable gas with a flashpoint below 60°C is likely to occur in normal operation.

.3 *Zone 2* is an area in which an explosive gas atmosphere or a flammable gas with a flashpoint below 60°C is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only.

1.3.13 *Non-hazardous area* means an area which is not considered to be hazardous, i.e. gas safe, provided certain conditions are being met.

1.3.14 *High-pressure piping* means gas fuel piping with maximum working pressure greater than 10 bar.

1.3.15 *IEC* means the International Electrotechnical Commission.

1.3.16 *IGC Code* means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as amended.

1.3.17 *LEL* means the lower explosive limit.

1.3.18 *LNG* means liquefied natural gas (refer to 1.3.22).

1.3.19 *Main tank valve* means a remote operated valve on the gas outlet from a gas storage tank, located as close to the tank outlet point as possible.

1.3.20 *MARVS* means the maximum allowable relief valve setting of a gas tank.

1.3.21 *Master gas fuel valve* means an automatic valve in the gas supply line to each engine located outside the machinery space for gas-fuelled engines and as close to the gas heater (if fitted) as possible.

---

[3] Refer also to the area classification specified in Sec. 2.5 of IEC 60079-10-1:2008 Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres.

1.3.22 *Natural gas* means a gas without condensation at common operating pressures and temperatures where the predominant component is methane with some ethane and small amounts of heavier hydrocarbons (mainly propane and butane).

1.3.23 *Open deck* means a deck that is open on both ends, or is open on one end and equipped with adequate natural ventilation that is effective over the entire length of the deck through permanent openings distributed in the side panels or in the deck above.

1.3.24 *Organization* means the International Maritime Organization (IMO).

1.3.25 *Risk* means the expression of the danger that an undesired event represents to persons, to the environment or to material property. The risk is expressed by the probability and consequences of an accident.

1.3.26 *Recognized standards* means applicable international or national standards acceptable to the Administration or standards laid down and maintained by an organization which complies with the standards adopted by the Organization and which is recognized by the Administration.

1.3.27 *Safety management system* means the international safety management system as described in the ISM Code.

1.3.28 *Second barrier* means a technical measure which prevents the occurrence of a hazard if the first barrier fails, e.g., second housing of a tank protecting the surroundings from the effect of tank leaks.

1.3.29 *Semi-enclosed space* means a space limited by decks and or bulkheads in such manner that the natural conditions of ventilation are notably different from those obtained on open deck[4].

1.3.30 *Single gas fuel engine* means a power generating engine capable of operating on gas-only, and not able to switch over to oil fuel operation.

1.3.31 *SOLAS Convention* means the International Convention for the Safety of Life at Sea, 1974, as amended.

1.3.32 *Source of release* means any valve, detachable pipe joint, pipe packing, compressor or pump seal in the gas fuel system.

1.3.33 *Tank room* means the gastight space surrounding the bunker tank, containing all tank connections and all tank valves.

1.4 Survey requirements

1.4.1 Surveys should be performed and certificates issued in accordance with the provisions of SOLAS 1974, as modified by its 1988 Protocol and as amended, chapter 1, part B, regulation 6 or 7, as applicable[5].

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[4] Refer also to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features.

[5] Refer to the Revised survey guidelines under the harmonized system of survey and certification (resolution A.997(25)).

CHAPTER 2

SHIP ARRANGEMENTS AND SYSTEM DESIGN

2.1 General

2.1.1 For any new or altered concept or configuration a risk analysis should be conducted in order to ensure that any risks arising from the use of gas-fuelled engines affecting the structural strength and the integrity of the ship are addressed. Consideration should be given to the hazards associated with installation, operation, and maintenance, following any reasonably foreseeable failure.

2.1.2 The risks should be analysed using acceptable and recognized risk analysis techniques and loss of function, component damage, fire, explosion and electric shock should as a minimum be considered. The analysis should ensure that risks are eliminated wherever possible. Risks which cannot be eliminated should be mitigated as necessary. Details of risks, and the means by which they are mitigated, should be included in the operating manual.

2.1.3 An explosion in any space containing open gas sources should not:

.1 cause damage to any space other than that in which the incident occurs;

.2 disrupt the proper functioning of other zones;

.3 damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur;

.4 damage work areas or accommodation in such a way that people who stay in such areas under normal operating conditions are injured;

.5 disrupt the proper functioning of control stations and switchboard rooms for necessary power distribution;

.6 damage life-saving equipment or associated launching arrangements;

.7 disrupt the proper functioning of fire-fighting equipment located outside the explosion-damaged space; or

.8 affect other areas in the vessel in such a way that chain reactions involving, *inter alia*, cargo, gas and bunker oil may arise.

2.2 Material requirements

2.2.1 Materials used in gas tanks, gas piping, process pressure vessels and other components in contact with gas should be in accordance with IGC Code, chapter 6, Materials of construction. For CNG tanks, the use of materials not covered by the IGC Code may be specially considered by the Administration.

2.2.2 Materials for piping system for liquefied gases should comply with the requirements of the IGC Code, section 6.2. Some relaxation may, however, be permitted in the quality of the material of open-ended vent piping, provided the temperature of the gas at atmospheric pressure is -55°C or higher, and provided no liquid discharge to the vent piping can occur. Materials should in general be in accordance with recognized standards.

2.2.3 Materials having a melting point below 925°C should not be used for piping outside the gas tanks except for short lengths of pipes attached to the gas tanks, in which case the low melting point materials should be wrapped in class A-60 insulation.

2.3 Location and separation of spaces

2.3.1 *The arrangement and location of spaces*

The arrangement and location of spaces for gas fuel storage, distribution and use should be such that the number and extent of hazardous areas is kept to a minimum.

2.3.2 *Gas compressor room*

2.3.2.1 Compressor rooms, if arranged, should be located above freeboard deck, unless those rooms are arranged and fitted in accordance with the requirements of these Guidelines for tank rooms.

2.3.2.2 If compressors are driven by shafting passing through a bulkhead or deck, the bulkhead penetration should be of gastight type.

2.3.3 *Machinery spaces containing gas-fuelled engines*

2.3.3.1 When more than one machinery space is required for gas-fuelled engines and these spaces are separated by a single bulkhead, the arrangements should be such that the effects of a gas explosion in either space can be contained or vented without affecting the integrity of the adjacent space and equipment within that space.

2.3.3.2 ESD-protected machinery spaces for gas-fuelled engines should have as simple a geometrical shape as possible.

2.3.4 *Tank rooms*

2.3.4.1 Tank room boundaries including access doors should be gastight.

2.3.4.2 The tank room should not be located adjacent to machinery spaces of category A. If the separation is by means of a cofferdam the separation should be at least 900 mm and insulation to class A-60 should be fitted on the engine-room side.

2.4 Arrangement of entrances and other openings

2.4.1 Direct access through doors, gastight or otherwise, should generally not be permitted from a gas-safe space to a gas-dangerous space. Where such openings are necessary for operational reasons, an air lock which complies with the requirements of chapter 3.6 (2 to 7) of the IGC Code should be provided.

2.4.2 If the compressor room is approved located below deck, the room should, as far as practicable, have an independent access direct from the open deck. Where a separate access from deck is not practicable, an air lock which complies with the requirements of chapter 3.6 (2 to 7) of the IGC Code should be provided.

2.4.3 The tank room entrance should be arranged with a sill height of at least 300 mm.

2.4.4 Access to the tank room should as far as practicable be independent and direct from open deck. If the tank room is only partially covering the tank, this requirement should also apply to the room surrounding the tank and where the opening to the tank room is located. Where a separate access from deck is not practicable, an air lock which complies with the requirements of chapter 3.6 (2 to 7) of the IGC Code should be provided. The access trunk should be fitted with separate ventilation. It should not be possible to have unauthorized access to the tank room during normal operation of the gas system.

2.4.5 If the access to an ESD-protected machinery space is from another enclosed space in the ship, the entrances should be arranged with self-closing doors. An audible and visual alarm should be provided at a permanent manned location. Alarm should be given if the door is open continuously for more than 1 min. As an alternative, an arrangement with two self-closing doors in series may be acceptable.

2.5 General pipe design

2.5.1 The requirements of this section apply to gas piping. The Administration may accept relaxation from these requirements for gas piping inside gas tanks and open-ended piping after special consideration, such as risk assessment.

2.5.2 Gas piping should be protected against mechanical damage and the piping should be capable of assimilating thermal expansion without developing substantial tension.

2.5.3 The piping system should be joined by welding with a minimum of flange connections. Gaskets should be protected against blow-out.

2.5.4 The wall thickness of pipes should not be less than:

$$t = \frac{t_0 + b + c}{1 - \frac{a}{100}} \text{ (mm)}$$

where:

t_0 = theoretical thickness
t_0 = $pD/(20Ke + p)$

where:

p = design pressure (bar), refer to 2.5.5.

D = outside diameter (mm).

K = allowable stress (N/mm^2), refer to 2.5.6.

e = efficiency factor equal to 1 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, which are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with recognized standards. In other cases an efficiency factor value depending on the manufacturing process may be determined by the Administration.

b = allowance for bending (mm). The value of b should be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not give, b should be:

$$\mathrm{b} = \frac{Dt_0}{2.5r} \text{ (mm)}$$

with:

r = mean radius of the bend (mm).

c = corrosion allowance (mm). If corrosion allowance or erosion is expected, the wall thickness of the piping should be increased over that required by other design requirements. This allowance should be consistent with the expected life of the piping.

a = negative manufacturing tolerance for thickness (%).

The minimum wall thickness should be in accordance with recognized standards.

2.5.5 The greater of the following design conditions should be used for piping, piping system and components as appropriate:

.1 for systems or components which may be separated from their relief valves and which contain only vapour at all times, the superheated vapour pressure at 45°C or higher or lower if agreed upon by the Administration (refer to IGC Code, paragraph 4.2.6.2), assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or

.2 the MARVS of the gas tanks and gas processing systems; or

.3 the pressure setting of the associated pump or compressor discharge relief valve if of sufficient capacity; or

.4 the maximum total discharge or loading head of the gas piping system; or

.5 the relief valve setting on a pipeline system if of sufficient capacity; or

.6 a pressure of 10 bar except for open-ended lines where it is not to be less than 5 bar.

2.5.6 For pipes made of steel including stainless steel, the allowable stress to be considered in the formula of the strength thickness in 2.5.4 should be the lower of the following values:

$$\frac{R_m}{A} \text{ or } \frac{R_e}{B}$$

where:

R_m = specified minimum tensile strength at room temperature (N/mm^2).

R_e = specified lower minimum yield stress or 0.2% proof stress at room temperature (N/mm^2).

A = 2.7.

B = 1.8.

For pipes made of materials other than steel, the allowable stress should be considered by the Administration.

2.5.7 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipe due to superimposed loads from supports, ship deflection or other causes, the wall thickness should be increased over that required by 2.5.4 or, if this is impractical or would cause excessive local stresses, these loads should be reduced, protected against or eliminated by other design methods.

2.5.8 Gas piping systems should have sufficient constructive strength. For high pressure gas piping systems this should be confirmed by carrying out stress analysis and taking into account:

.1 stresses due to the weight of the piping system;

.2 acceleration loads when significant; and

.3 internal pressure and loads induced by hog and sag of the ship.

2.5.9 Flanges, valves, fittings, etc., should be in accordance with recognized standards taking into account the design pressure defined in 2.5.5. For bellows and expansion joints used in vapour service, a lower minimum design pressure than defined in 2.5.5 may be accepted.

2.5.10 All valves and expansion joints used in high pressure gas systems should be of an approved type.

2.5.11 The following types of connections may be considered for direct connection of pipe lengths (without flanges):

.1 Butt welded joints with complete penetration at the root may be used in all applications. For design temperature below -10°C, butt welds should be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass. For design pressures in excess of 10 bar and design temperatures -10°C or lower, backing rings should be removed.

.2 Slip-on welded joints with sleeves and related welding, having dimensions satisfactory to the Administration, should only be used for open-ended lines with external diameter of 50 mm or less and design temperatures not lower than -55°C.

.3 Screwed couplings should only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

2.5.12 Flanges should be of the welding neck, slip-on or socket welding type. For all piping (except open-ended lines), the following apply:

.1 For design temperatures < -55°C only welding neck flanges should be used.

.2 For design temperatures < -10°C slip-on flanges should not be used in nominal sizes above 100 mm and socket welding flanges should not be used in nominal sizes above 50 mm.

2.5.13 Piping connections other than those mentioned above may be accepted upon consideration in each case.

2.5.14 Postweld heat treatment should be required for all butt welds of pipes made with carbon, carbon-manganese and low-alloy steels. The Administration may waive the requirement for thermal stress relieving of pipes having wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.

2.5.15 When the design temperature is -110°C or lower, a complete stress analysis for each branch of the piping system should be submitted. This analysis should take into account all stresses due to weight of pipes with cargo (including acceleration if significant), internal pressure, thermal contraction and loads induced by movements of the ship. For temperatures above -110°C, a stress analysis may be required by the Administration. In any case, consideration should be given to thermal stresses, even if calculations need not be submitted. The analysis should be carried out according to a recognized code of practice.

2.5.16 Gas pipes should not be located less than 760 mm from the ship's side.

2.5.17 Gas piping should not be led through other machinery spaces. Alternatively, double gas piping may be approved, provided the danger of mechanical damage is negligible, the gas piping has no discharge sources and the room is equipped with a gas alarm.

2.5.18 An arrangement for purging gas bunkering lines and supply lines (only up to the double block and bleed valves if these are located close to the engine) with nitrogen should be provided.

2.5.19 The gas piping system should be installed with sufficient flexibility. Arrangement for provision of the necessary flexibility should be demonstrated to maintain the integrity of the piping system in all foreseen service situations.

2.5.20 Gas pipes should be colour marked based on a recognized standard[6].

6 Refer to EN ISO 14726:2008 Ships and marine technology – Identification colours for the content of piping systems.

2.5.21 If the fuel gas contains heavier components that may condense in the system, knock out drums or equivalent means for safely removing the liquid should be fitted.

2.5.22 All pipelines and components which may be isolated containing liquid gas should be provided with relief valves.

2.5.23 Where tanks or piping are separated from the ship's structure by thermal isolation, provision should be made for electrically bonding to the ship's structure both the piping and the tanks. All gasketed pipe joints and hose connections should be electrically bonded.

2.6 System configuration

2.6.1 *Alternative system configurations*

2.6.1.1 Two alternative system configurations may be accepted:

.1 *Gas safe machinery spaces*: Arrangements in machinery spaces are such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas safe.

.2 *ESD-protected machinery spaces*: Arrangements in machinery spaces are such that the spaces are considered non-hazardous under normal conditions, but under certain abnormal conditions may have the potential to become hazardous. In the event of abnormal conditions involving gas hazards, emergency shutdown (ESD) of non-safe equipment (ignition sources) and machinery is to be automatically executed while equipment or machinery in use or active during these conditions are to be of a certified safe type.

2.6.2 *Gas safe machinery spaces*

2.6.2.1 All gas supply piping within machinery space boundaries should be enclosed in a gastight enclosure, i.e. double wall piping or ducting.

2.6.2.2 In case of leakage in a gas supply pipe making shutdown of the gas supply necessary, a secondary independent fuel supply should be available. Alternatively, in the case of multi-engine installations, independent and separate gas supply systems for each engine or group of engines may be accepted.

2.6.2.3 For single fuel installations (gas only), the fuel storage should be divided between two or more tanks of approximately equal size. The tanks should be located in separate compartments.

2.6.3 *ESD-protected machinery spaces*

2.6.3.1 Gas supply piping within machinery spaces may be accepted without a gastight external enclosure on the following conditions:

.1 Engines for generating propulsion power and electric power should be located in two or more machinery spaces not having any common boundaries unless it can be documented that the common boundary can withstand an explosion in one of the rooms. Distribution of engines between the different machinery spaces should be such that in the case of shutdown of fuel supply to any one machinery space it is possible to maintain at least 40% of the propulsion power plus normal electrical power supply for sea-going services. Incinerators, inert gas generators or other oil fired boilers should not be located within an ESD-protected machinery space.

.2 The gas machinery, tank and valve installation spaces should contain only a minimum of such necessary equipment, components and systems as are required to ensure that any piece of equipment in each individual space maintains its principal function.

.3 Pressure in gas supply lines within machinery spaces should be less than 10 bar, e.g., this concept can only be used for low pressure systems.

.4 A gas detection system arranged to automatically shutdown the gas supply (also oil fuel supply if dual fuel) and disconnect all non-explosion protected equipment or installations should be fitted, as outlined in 5.5 and 5.6.

2.6.3.2 For single fuel installations (gas only), the fuel storage should be divided between two or more tanks of approximately equal size. The tanks should be located in separate compartments.

2.7 Gas supply system in gas machinery spaces

2.7.1 *Gas supply system for gas safe machinery spaces*

2.7.1.1 Gas supply lines passing through enclosed spaces should be completely enclosed by a double pipe or duct. This double pipe or duct should fulfil one of the following:

.1 the gas piping should be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes should be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms should be provided to indicate a loss of inert gas pressure between the pipes. When the inner pipe contains high pressure gas, the system should be so arranged that the pipe between the master gas valve and the engine is automatically purged with inert gas when the master gas valve is closed; or

.2 the gas fuel piping should be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the wall of the outer pipe or duct should be equipped with mechanical under pressure ventilation having a capacity of at least 30 air changes per hour. This ventilation capacity may be reduced to 10 air changes per hour provided automatic filling of the duct with nitrogen upon detection of gas is arranged for. The fan motors should comply with the required explosion protection in the installation area. The ventilation outlet should be covered by a protection screen and placed in a position where no flammable gas-air mixture may be ignited.

2.7.1.2 The connecting of gas piping and ducting to the gas injection valves should be so as to provide complete coverage by the ducting. The arrangement should facilitate replacement and/or overhaul of injection valves and cylinder covers. The double ducting should be required also for gas pipes on the engine itself, and all the way until gas is injected into the chamber.[7]

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[7] If gas is supplied into the air inlet on a low pressure engine, double ducting may be omitted on the air inlet pipe on the condition that a gas detector is fitted above the engine.

2.7.1.3 For high-pressure piping the design pressure of the ducting should be taken as the higher of the following:

.1 the maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space;

.2 local instantaneous peak pressure in way of the rupture: this pressure is to be taken as the critical pressure and is given by the following expression:

$$p^* = p_0 \left(\frac{2}{k+1} \right)^{\frac{k}{k-1}}$$

where:

p_0 = maximum working pressure of the inner pipe

k = C_p/C_v constant pressure specific heat divided by the constant volume specific heat

k = 1.31 for CH_4

The tangential membrane stress of a straight pipe should not exceed the tensile strength divided by 1.5 ($R_m/1.5$) when subjected to the above pressures. The pressure ratings of all other piping components should reflect the same level of strength as straight pipes.

As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports should then be submitted.

2.7.1.4 For low pressure piping the duct should be dimensioned for a design pressure not less than the maximum working pressure of the gas pipes. The duct should also be pressure tested to show that it can withstand the expected maximum pressure at gas pipe rupture.

2.7.1.5 The arrangement and installation of the high-pressure gas piping should provide the necessary flexibility for the gas supply piping to accommodate the oscillating movements of the main engine, without running the risk of fatigue problems. The length and configuration of the branch lines are important factors in this regard.

2.7.2 *Gas supply system for ESD-protected machinery spaces*

2.7.2.1 The pressure in the gas supply system should not exceed 10 bar.

2.7.2.2 The gas supply lines should have a design pressure not less than 10 bar.

2.8 Gas fuel storage

2.8.1 *Liquefied gas storage tanks*

2.8.1.1 The storage tank used for liquefied gas should be an independent tank designed in accordance with the IGC Code, chapter 4.

2.8.1.2 Pipe connections to the tank should normally be mounted above the highest liquid level in the tanks. However, connections below the highest liquid level may be accepted after special consideration by the Administration.

2.8.1.3 Pressure relief valves as required in the IGC Code chapter 8 should be fitted.

2.8.1.4 The outlet from the pressure relief valves should normally be located at least B/3 or 6 m, whichever is greater, above the weather deck and 6 m above the working area and gangways, where B is the greatest moulded breadth of the ship in metres. The outlets should normally be located at least 10 m from the nearest:

.1 air intake, air outlet or opening to accommodation, service and control spaces, or other gas safe spaces; and

.2 exhaust outlet from machinery or from furnace installation.

2.8.1.5 Storage tanks for liquid gas should not be filled to more than 98% full at the reference temperature, where the reference temperature is as defined in the IGC Code, paragraph 15.1.4. A filling limit curve for actual filling temperatures should be prepared from the formula given in the IGC Code, paragraph 15.1.2. However, when the tank insulation and tank location makes the probability very small for the tank contents to be heated up due to external fire, special considerations may be made to allow a higher filling limit than calculated using the reference temperature, but never above 95%.

2.8.1.6 Means that are not dependent on the gas machinery system should be provided whereby liquid gas in the storage tanks can be emptied.

2.8.1.7 It should be possible to empty, purge gas and vent bunker tanks with gas piping systems. Procedures should be prepared for this. Inerting should be performed with, for instance, nitrogen, CO_2 or argon prior to venting to avoid an explosion hazardous atmosphere in tanks and gas pipes.

2.8.2 *Compressed gas storage tanks*

2.8.2.1 The storage tanks to be used for compressed gas should be certified and approved by the Administration.

2.8.2.2 Tanks for compressed gas should be fitted with pressure relief valves with a set point below the design pressure of the tank and with outlet located as required in 2.8.1.4.

2.8.3 *Storage on open deck*

2.8.3.1 Both gases of the compressed and the liquefied type may be accepted stored on open deck.

2.8.3.2 The storage tanks or tank batteries should be located at least B/5 from the ship's side. For ships other than passenger ships a tank location closer than B/5 but not less than 760 mm from the ship's side may be accepted.

2.8.3.3 The gas storage tanks or tank batteries and equipment should be located to assure sufficient natural ventilation, so as to prevent accumulation of escaped gas.

2.8.3.4 Tanks for liquid gas with a connection below the highest liquid level (see 2.8.1.2) should be fitted with drip trays below the tank which should be of sufficient capacity to contain the volume which could escape in the event of a pipe connection failure. The material of the drip tray should be stainless steel, and there should be efficient separation or isolation so that the hull or deck structures are not exposed to unacceptable cooling, in case of leakage of liquid gas.

2.8.4 ***Storage in enclosed spaces***

2.8.4.1 Gas in a liquid state may be stored in enclosed spaces, with a maximum acceptable working pressure of 10 bar. Storage of compressed gas in enclosed spaces and location of gas tanks with a higher pressure than 10 bar in enclosed spaces is normally not acceptable, but may be permitted after special consideration and approval by the Administration provided the following is fulfilled in addition to 2.8.4.3:

.1 adequate means are provided to depressurize the tank in case of a fire which can affect the tank; and

.2 all surfaces within the tank room are provided with suitable thermal protection against any lost high-pressure gas and resulting condensation unless the bulkheads are designed for the lowest temperature that can arise from gas expansion leakage; and

.3 a fixed fire-extinguishing system is installed in the tank room.

2.8.4.2 The gas storage tank(s) should be placed as close as possible to the centreline:

.1 minimum, the lesser of B/5 and 11.5 m from the ship side;

.2 minimum, the lesser of B/15 and 2 m from the bottom plating;

.3 not less than 760 mm from the shell plating.

For ships other than passenger ships and multi-hulls, a tank location closer than B/5 from the ship side may be accepted.

2.8.4.3 The storage tank and associated valves and piping should be located in a space designed to act as a second barrier, in case of liquid or compressed gas leakage. The material of the bulkheads of this space should have the same design temperature as the gas tank, and the space should be designed to withstand the maximum pressure build-up. Alternatively, pressure relief venting to a safe location (mast) can be provided. The space should be capable of containing leakage, and is to be isolated thermally so that the surrounding hull is not exposed to unacceptable cooling, in case of leakage of the liquid or compressed gas. This second barrier space is in other parts of these Guidelines called "tank room". When the tank is double walled and the outer tank shell is made of cold resistant material, a tank room could be arranged as a box fully welded to the outer shell of the tank, covering all tank connections and valves, but not necessarily all of the outer tank shell.

2.8.4.4 The tank room may be accepted as the outer shell of a stainless steel vacuum insulated tank in combination with a stainless steel box welded to the outer shell, containing all tank pipe connections, valves, piping, etc. In this case the requirements for ventilation and gas detection should be made applicable to the box, but not to the double barrier of the tank.

2.8.4.5 Bilge suctions from the tank room, if provided, should not be connected to the bilge system for the rest of the ship.

2.9 Fuel bunkering system and distribution system outside machinery spaces

2.9.1 *Fuel bunkering station*

2.9.1.1 The bunkering station should be so located that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations should be subject to special consideration. The bunkering station should be physically separated or structurally shielded from accommodation, cargo/working deck and control stations. Connections and piping should be so positioned and arranged that any damage to the gas piping does not cause damage to the vessel's gas storage tank arrangement leading to uncontrolled gas discharge.

2.9.1.2 Drip trays should be fitted below liquid gas bunkering connections and where leakage may occur. The drip trays should be made of stainless steel, and should be drained over the ship's side by a pipe that preferably leads down near the sea. This pipe could be temporarily fitted for bunkering operations. The surrounding hull or deck structures should not be exposed to unacceptable cooling, in case of leakage of liquid gas. For compressed gas bunkering stations, low temperature steel shielding should be provided to prevent the possible escape of cold jets impinging on surrounding hull structure.

2.9.1.3 Control of the bunkering should be possible from a safe location in regard to bunkering operations. At this location tank pressure and tank level should be monitored. Overfill alarm and automatic shutdown should also be indicated at this location.

2.9.2 *Bunkering system*

2.9.2.1 The bunkering system should be so arranged that no gas is discharged to air during filling of storage tanks.

2.9.2.2 A manually-operated stop valve and a remote operated shutdown valve in series, or a combined manually-operated and remote valve should be fitted in every bunkering line close to the shore connecting point. It should be possible to release the remote-operated valve in the control location for bunkering operations and or another safe location.

2.9.2.3 If the ventilation in the ducting around the gas bunkering lines stops, an audible and visual alarm should be provided at bunkering control location.

2.9.2.4 If gas is detected in the ducting around the bunkering lines an audible and visual alarm should be provided at the bunkering control location.

2.9.2.5 Means should be provided for draining the liquid from the bunkering pipes at bunkering completion.

2.9.2.6 Bunkering lines should be arranged for inerting and gas freeing. During operation of the vessel the bunkering pipes should be gas free.

2.9.3 *Distribution outside of machinery spaces*

2.9.3.1 Gas fuel piping should not be led through accommodation spaces, service spaces or control stations.

2.9.3.2 Where gas pipes pass through enclosed spaces in the ship, they should be enclosed in a duct. This duct should be mechanically under pressure ventilated with 30 air changes per hour, and gas detection as required in 5.5 should be provided.

2.9.3.3 The duct should be dimensioned according to 2.7.1.3 and 2.7.1.4.

2.9.3.4 The ventilation inlet for the duct should always be located in open air, away from ignition sources.

2.9.3.5 Gas pipes located in open air should be so located that they are not likely to be damaged by accidental mechanical impact.

2.9.3.6 High-pressure gas lines outside the machinery spaces containing gas-fuelled engines should be installed and protected so as to minimize the risk of injury to personnel in case of rupture.

2.10 Ventilation system

2.10.1 *General*

2.10.1.1 Any ducting used for the ventilation of hazardous spaces should be separate from that used for the ventilation of non-hazardous spaces. The ventilation should function at all temperature conditions the ship will be operating in. Electric fan motors should not be located in ventilation ducts for hazardous spaces unless the motor is certified for the same hazard zone as the space served.

2.10.1.2 Design of ventilation fans serving spaces containing gas sources should fulfil the following:

.1 Electric motors driving fans should comply with the required explosion protection in the installation area. Ventilation fans should not produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, should be of non-sparking construction defined as:

  .1 impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;

  .2 impellers and housings of non-ferrous metals;

  .3 impellers and housing of austenitic stainless steel;

  .4 impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing; or

  .5 any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

.2 In no case should the radial air gap between the impeller and the casing be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm.

.3 Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and should not be used in these places.

.4 The installation on board of the ventilation units should be such as to ensure the safe bonding to the hull of the units themselves.

2.10.1.3 Any loss of the required ventilating capacity should give an audible and visual alarm at a permanently manned location.

2.10.1.4 Required ventilation systems to avoid any gas accumulation should consist of independent fans, each of sufficient capacity, unless otherwise specified in these Guidelines.

2.10.1.5 Air inlets for hazardous enclosed spaces should be taken from areas which, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces should be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct should have over-pressure relative to this space, unless mechanical integrity and gastightness of the duct will ensure that gases will not leak into it.

2.10.1.6 Air outlets from non-hazardous spaces should be located outside hazardous areas.

2.10.1.7 Air outlets from hazardous enclosed spaces should be located in an open area which, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

2.10.1.8 The required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form.

2.10.1.9 Non-hazardous spaces with opening to a hazardous area should be arranged with an air-lock and be maintained at overpressure relative to the external hazardous area. The overpressure ventilation should be arranged according to the following requirements:

.1 During initial start-up or after loss of overpressure ventilation, before energizing any electrical installations not certified safe for the space in the absence of pressurization, it should be required to:

  .1 proceed with purging (at least 5 air changes) or confirm by measurements that the space is non-hazardous; and

  .2 pressurize the space.

.2 Operation of the overpressure ventilation should be monitored.

.3 In the event of failure of the overpressure ventilation:

  .1 an audible and visual alarm should be given at a manned location; and

  .2 if overpressure cannot be immediately restored, automatic or programmed disconnection of electrical installations according to a recognized standard[8].

[8] Refer to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features, table 5.

2.10.2 ***Tank room***

2.10.2.1 The tank room for gas storage should be provided with an effective mechanical forced ventilation system of the under pressure type, providing a ventilation capacity of at least 30 air changes per hour. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations should be demonstrated by a safety analysis.

2.10.2.2 Approved automatic fail-safe fire dampers should be fitted in the ventilation trunk for tank room.

2.10.3 ***Machinery spaces containing gas-fuelled engines***

2.10.3.1 The ventilation system for machinery spaces containing gas-fuelled engines should be independent of all other ventilation systems.

2.10.3.2 ESD-protected machinery spaces should have ventilation with a capacity of at least 30 air changes per hour. The ventilation system should ensure a good air circulation in all spaces, and in particular ensure that any formation of gas pockets in the room are detected. As an alternative, arrangements whereby under normal operation the machinery spaces is ventilated with at least 15 air changes an hour is acceptable provided that, if gas is detected in the machinery space, the number of air changes will automatically be increased to 30 an hour.

2.10.3.3 The number and power of the ventilation fans should be such that the capacity is not reduced by more than 50% of the total ventilation capacity, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is out of action.

2.10.4 ***Pump and compressor rooms***

2.10.4.1 Pump and compressor rooms should be fitted with effective mechanical ventilation system of the under pressure type, providing a ventilation capacity of at least 30 air changes per hour.

2.10.4.2 The number and power of the ventilation fans should be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is out of action.

2.10.4.3 Ventilation systems for pump and compressor rooms should be in operation when pumps or compressors are working.

2.10.4.4 When the space is dependent on ventilation for its area classification, the following should apply:

.1 During initial start-up, and after loss of ventilation, the space should be purged (at least 5 air changes), before connecting electrical installations which are not certified for the area classification in absence of ventilation. Warning notices to this effect should be placed in an easily visible position near the control stand.

.2 Operation of the ventilation should be monitored.

.3 In the event of failure of ventilation, the following should apply:

.1 an audible and visual alarm should be given at a manned location;

.2 immediate action should be taken to restore ventilation; and

.3 electrical installations should be disconnected[9] if ventilation cannot be restored for an extended period. The disconnection should be made outside the hazardous areas, and be protected against unauthorized reconnection, e.g., by lockable switches.

CHAPTER 3

FIRE SAFETY

3.1 General

3.1.1 The requirements in this chapter are additional to those given in SOLAS chapter II-2.

3.1.2 A compressor room should be regarded as a machinery space of category A for fire protections purposes.

3.2 Fire protection

3.2.1 Tanks or tank batteries located above deck should be shielded with class A-60 insulation towards accommodation, service stations, cargo spaces and machinery spaces.

3.2.2 The tank room boundaries and ventilation trunks to such spaces below the bulkhead deck should be constructed to class A-60. However, where the room is adjacent to tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces, the insulation standard may be reduced to class A-0.

3.2.3 The fire and mechanical protection of gas pipes lead through ro-ro spaces on open deck should be subject to special consideration by the Administration depending on the use and expected pressure in the pipes. Gas pipes lead through ro-ro spaces on open deck should be provided with guards or bollards to prevent vehicle collision damage.

3.2.4 The bunkering station should be separated by class A-60 divisions towards other spaces, except for spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces where the insulation standard may be reduced to class A-0.

3.2.5 When more than one machinery space is required and these spaces are separated by a single bulkhead, the bulkhead should be class A-60.

3.2.6 A compressor room in a ship not subject to the IGC Code should be regarded as a machinery space of category A for fire insulation requirements.

[9] Intrinsically safe equipment suitable for zone 0 is not required to be switched off. Certified flameproof lighting may have a separate switch-off circuit.

3.3 Fire extinction

3.3.1 *Fire main*

3.3.1.1 The water spray system required below may be part of the fire main system provided that the required fire pump capacity and working pressure is sufficient to operation of both the required numbers of hydrants and hoses and the water spray system simultaneously.

3.3.1.2 When the storage tank is located on open deck, isolating valves should be fitted in the fire main in order to isolate damage sections of the main. Isolation of a section of fire main shall not deprive the fire line ahead of the isolated section of water.

3.3.2 *Water spray systems*

3.3.2.1 A water spray system should be fitted for cooling and fire prevention and to cover exposed parts of gas storage tank located above deck.

3.3.2.2 The system should be designed to cover all areas as specified above with an application rate of 10 *l*/min/m^2 for horizontal projected surfaces and 4 *l*/min/m^2 for vertical surfaces.

3.3.2.3 For the purpose of isolating damage sections, stop valves should be fitted at least every 40 m or the system may be divided into two or more sections with control valves located in a safe and readily accessible position not likely to be cut-off in case of fire.

3.3.2.4 The capacity of the water spray pump should be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified above in the areas protected.

3.3.2.5 A connection to the ship's fire main through a stop valve should be provided.

3.3.2.6 Remote start of pumps supplying the water spray system and remote operation of any normally closed valves to the system should be located in a readily accessible position which is not likely to be cut off in case of fire in the areas protected.

3.3.2.7 The nozzles should be of an approved full bore type and they should be arranged to ensure an effective distribution of water throughout the space being protected.

3.3.2.8 An equivalent system to the water spray system may be fitted provided it has been tested for its on-deck cooling capability to the satisfaction of the Administration.

3.3.3 *Dry chemical powder fire-extinguishing system*

3.3.3.1 In the bunkering station area a permanently installed dry chemical powder extinguishing system should cover all possible leak points. The capacity should be at least 3.5 kg/s for a minimum of 45 s discharges. The system should be arranged for easy manual release from a safe location outside the protected area.

3.3.3.2 One portable dry powder extinguisher of at least 5 kg capacity should be located near the bunkering station.

3.4 Fire detection and alarm system

3.4.1 *Detection*

3.4.1.1 An approved fixed fire detection system should be provided for the tank room and the ventilation trunk for tank room below deck.

3.4.1.2 Smoke detectors alone should not be considered sufficient for rapid fire detection.

3.4.1.3 Where the fire detection system does not include means of remotely identifying each detector individually, the detectors should be arranged on separate loops.

3.4.2 *Alarms and safety actions*

3.4.2.1 Required safety actions at fire detection in the machinery space containing gas-fuelled engines and tank room are given in table 1 of chapter V. In addition, the ventilation should stop automatically and fire dampers are to close.

CHAPTER 4

ELECTRICAL SYSTEMS

4.1 General

4.1.1 The provisions of this chapter should be applied in conjunction with applicable electrical requirements of part D of SOLAS chapter II-1.

4.1.2 Hazardous areas on open deck and other spaces not defined in this chapter should be decided based on a recognized standard[10]. The electrical equipment fitted within hazardous areas should be according to the same standard.

4.1.3 Electrical equipment and wiring should in general not be installed in hazardous areas unless essential for operational purposes based on a recognized standard[11].

4.1.4 Electrical equipment fitted in an ESD-protected machinery space should fulfil the following:

.1 In addition to fire and hydrocarbon detectors and fire and gas alarms, lighting and ventilation fans should be certified safe for hazardous area zone 1.

.2 All electrical equipment in a machinery space containing gas-fuelled engines, and not certified for zone 1 should be automatically disconnected, if gas concentrations above 20% LEL is detected on two detectors in the space containing gas-fuelled engines.

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[10] Refer to IEC standard 60092-502, part 4.4: Tankers carrying flammable liquefied gases as applicable.

[11] The type of equipment and installation requirements should comply with IEC standard 60092-502: IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features and IEC 60079-10-1:2008 Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres, according to the area classification.

4.1.5 There should be an equalization connection between the bunker supplier and the bunkering station on the ship when a flammable gas/liquid is transferred.

4.1.6 Cable penetrations should satisfy the requirements regulating the dispersion of gas.

4.2 Area classification

4.2.1 *General*

4.2.1.1 Area classification is a method of analysing and classifying the areas where explosive gas atmospheres may occur. The object of the classification is to allow the selection of electrical apparatus able to be operated safely in these areas.

4.2.1.2 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2[12]. See also 4.3 below.

4.2.1.3 Area classification of a space may be dependent on ventilation[13].

4.2.1.4 A space with opening to an adjacent hazardous area on open deck, may be made into a less hazardous or non-hazardous space, by means of overpressure. Requirements to such pressurization are given in 2.10.

4.2.1.5 Ventilation ducts should have the same area classification as the ventilated space.

4.3 Definition of hazardous area zones

4.3.1 *Hazardous area zone 0*

This zone includes:

.1 the interiors of gas tanks, any pipework of pressure-relief or other venting systems for gas tanks, pipes and equipment containing gas.[14]

4.3.2 *Hazardous area zone 1*

This zone includes:

.1 tank room;

.2 gas compressor room arranged with ventilation according to 2.10.4;

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12 Refer to standards IEC 60079-10-1:2008 Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres and guidance and informative examples given in IEC 60092-502:1999, Electrical Installations in Ships – Tankers – Special Features for tankers.

13 Refer to standard IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features for tankers, table 1.

14 Instrumentation and electrical apparatus in contact with the gas or liquid gas should be of a type suitable for zone 0. Temperature sensors installed in thermo wells, and pressure sensors without additional separating chamber should be of intrinsically safe type Ex-ia.

.3 areas on open deck, or semi-enclosed spaces on deck, within 3 m of any gas tank outlet, gas or vapour outlet[15], bunker manifold valve, other gas valve, gas pipe flange, gas pump-room ventilation outlets and gas tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

.4 areas on open deck or semi-enclosed spaces on deck, within 1.5 m of gas compressor and pump room entrances, gas pump and compressor room ventilation inlets and other openings into zone 1 spaces;

.5 areas on the open deck within spillage coamings surrounding gas bunker manifold valves and 3m beyond these, up to a height of 2.4 m above the deck;

.6 enclosed or semi-enclosed spaces in which pipes containing gas are located, e.g., ducts around gas pipes, semi-enclosed bunkering stations; and

.7 the ESD-protected machinery space is considered as non-hazardous area during normal operation, but changes to zone 1 in the event of gas leakage.

4.3.3 ***Hazardous area zone 2***

This zone includes:

.1 areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1[16].

CHAPTER 5

CONTROL, MONITORING AND SAFETY SYSTEMS

5.1 General

5.1.1 A local reading pressure gauge should be fitted between the stop valve and the connection to shore at each bunker pipe.

5.1.2 Pressure gauges should be fitted to gas pump discharge lines and to the bunkering lines.

5.1.3 A bilge well in each tank room surrounding an independent liquid gas storage tank should be provided with both a level indicator and a temperature sensor. Alarm should be given at high level in bilge well. Low temperature indication should lead to automatic closing of main tank valve.

5.2 Gas tank monitoring

5.2.1 Gas tanks should be monitored and protected against overfilling as required in the IGC Code, sections 13.2 and 13.3.

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15 Such areas are, for example, all areas within 3 m of gas tank hatches, ullage openings or sounding pipes for gas tanks located on open deck and gas vapour outlets.

16 Refer to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features or IEC 60079-10-1:2008 Explosive atmospheres – Part 10-1: Classification of areas, according to the area classification., as applicable if not otherwise specified in this standard.

5.2.2 Each tank should be monitored with at least one local indicating instrument for pressure and remote pressure indication at the control position. The pressure indicators should be clearly marked with the highest and lowest pressure permitted in the tank. In addition, high-pressure alarm, and if vacuum protection is required, low pressure alarm should be provided on the bridge. The alarms should be activated before the set pressures of the safety valves are reached.

5.3 Gas compressor monitoring

Gas compressors should be fitted with audible and visual alarms both on the bridge and in the engine-room. As a minimum the alarms should be in relation to low gas input pressure, low gas output pressure, high gas output pressure and compressor operation.

5.4 Gas engine monitoring

5.4.1 Additional to the instrumentation provided in accordance with SOLAS chapter II-1, Part C, indicators should be fitted on the navigation bridge, the engine control room and the manoeuvring platform for:

.1 operation of the engine in case of gas-only engines; or

.2 operation and mode of operation of the engine in the case of dual fuel engines.

5.4.2 Auxiliary systems where gas may leak directly into the system medium (lubricating oil, cooling water) should be equipped with appropriate gas extraction measures fitted directly after the outlet from the engine in order to prevent gas dispersion. The gas extracted from auxiliary systems media should be vented to a safe location in the open.

5.5 Gas detection

5.5.1 Permanently installed gas detectors should be fitted in the tank room, in all ducts around gas pipes, in machinery spaces of the ESD-protected type, compressor rooms and other enclosed spaces containing gas piping or other gas equipment without ducting. In each ESD-protected machinery space, two independent gas detector systems should be required.

5.5.2 The number of detectors in each space should be considered taking size, layout and ventilation of the space into account.

5.5.3 The detection equipment should be located where gas may accumulate and/or in the ventilation outlets. Gas dispersal analysis or a physical smoke test should be used to find the best arrangement.

5.5.4 An audible and visible alarm should be activated before the vapour concentration reaches 20% of the lower explosion limit (LEL). For ventilated ducts around gas pipes in the machinery spaces containing gas-fuelled engines, the alarm limit can be set to 30% LEL. The protective system should be activated at a LEL of 40%.

5.5.5 Audible and visible alarms from the gas detection equipment should be located on the bridge and in the engine control room.

5.5.6 Gas detection for gas pipe ducts and machinery spaces containing gas-fuelled engines should be continuous without delay.

5.6 Safety functions of gas supply systems

5.6.1 Each gas storage tank should be provided with a tank valve capable of being remote operated and should be located as close to the tank outlet as possible.

5.6.2 The main gas supply line to each engine or set of engines should be equipped with a manually operated stop valve and an automatically operated "master gas fuel valve" coupled in series or a combined manually and automatically operated valve. The valves should be situated in the part of the piping that is outside machinery space containing gas-fuelled engines, and placed as near as possible to the installation for heating the gas, if fitted. The master gas-fuel valve should automatically cut off the gas supply as given in table 1.

5.6.2.1 The automatic master gas fuel valve should be operable from a reasonable number of places in the machinery space containing gas-fuelled engines, from a suitable location outside the space and from the bridge.

5.6.3 Each gas consuming equipment should be provided with a set of "double block and bleed" valves. These valves should be arranged as outlined in .1 or .2 (respectively shown as alternatives 1 and 2 in figure 1) so that when automatic shutdown is initiated as given in table 1, this will cause the two gas fuel valves that are in series to close automatically and the ventilation valve to open automatically and:

.1 two of these valves should be in series in the gas fuel pipe to the gas consuming equipment. The third valve should be in a pipe that vents to a safe location in the open air that portion of the gas fuel piping that is between the two valves in series; or

.2 the function of one of the valves in series and the ventilation valve can be incorporated into one valve body, so arranged that the flow to the gas utilization unit will be blocked and the ventilation opened.

5.6.3.1 The two block valves should be of the fail-to-close type, while the ventilation valve should be fail-to-open.

5.6.3.2 The double block and bleed valves should also be used for normal stop of the engine.

5.6.4 In cases where the master gas fuel valve is automatically shutdown, the complete gas supply branch downstream of the double block and bleed valve should be ventilated, if reverse flow from the engine to the pipe must be assumed.

5.6.5 There should be one manually operated shutdown valve in the gas supply line to each engine upstream of the double block and bleed valves to assure safe isolation during maintenance on the engine.

5.6.6 For one-engine installations and multi-engine installations, where a separate master valve is provided for each engine, the master gas fuel valve and the double block and bleed valve functions can be combined. Examples for the high-pressure system are shown in figures 1 and 2.

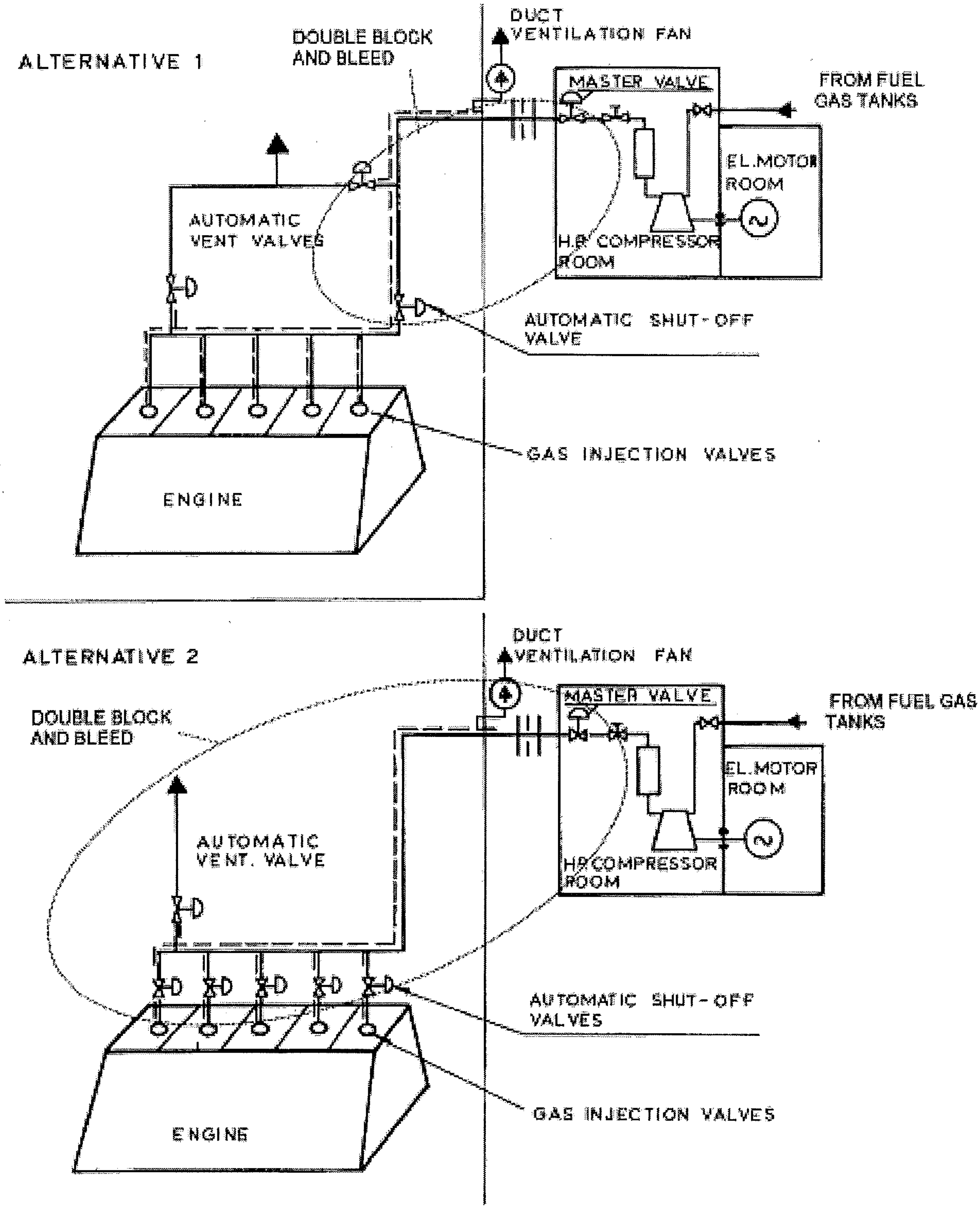

Figure 1

Alternative supply valve arrangements for high-pressure installations (single engine or separate master valve arrangement)

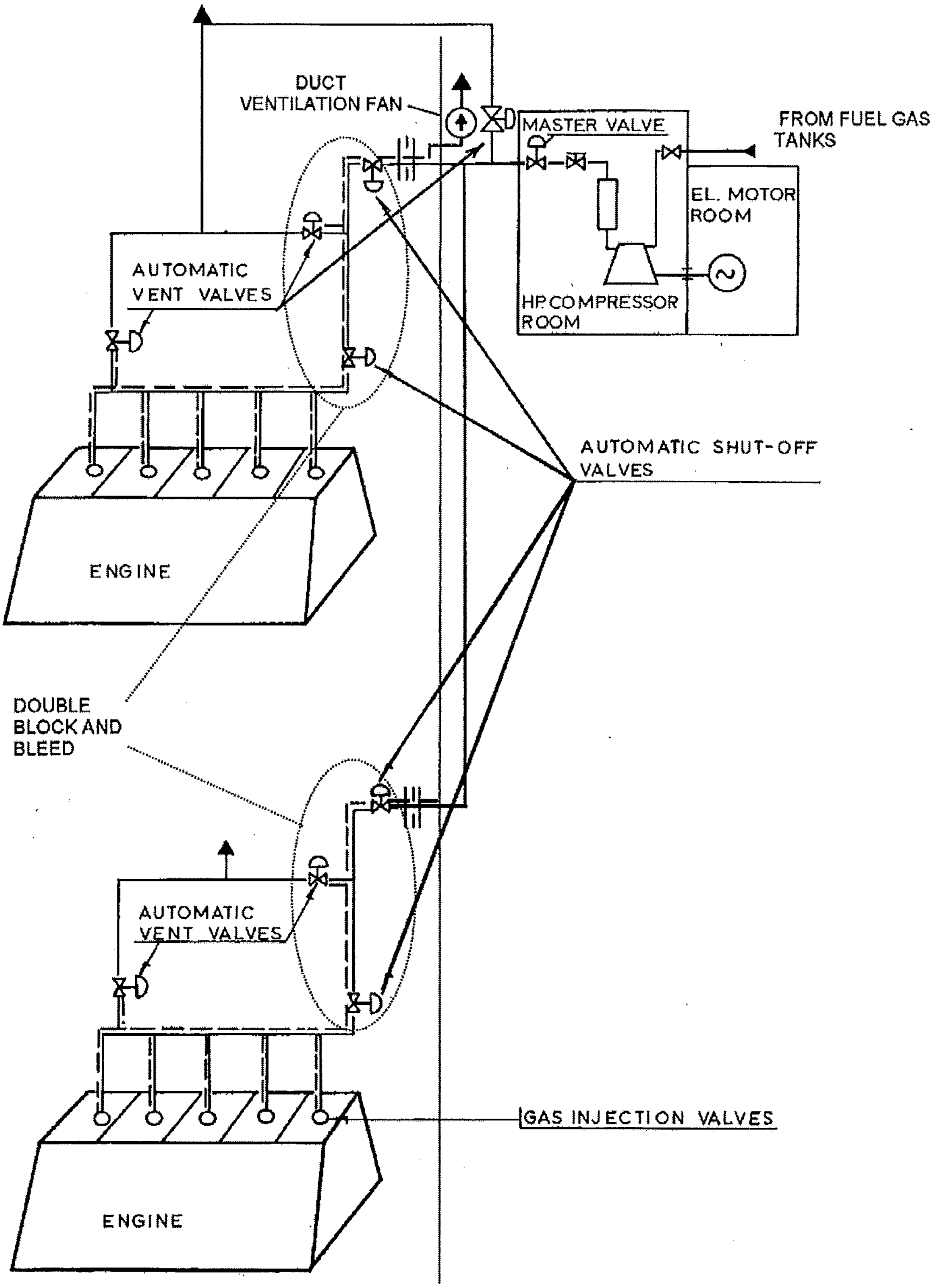

Figure 2

Alternative supply valve arrangements for high-pressure installations (multi-engine installation)

5.6.7 The total loss of ventilation in a machinery space for a single fuelled gas system should, additionally to what is given in table 1, lead to one of the following actions:

.1 *For a gas electric propulsion system with more than one machinery space*: Another engine should start. When the second engine is connected to bus-bar, the first engine should be shutdown automatically.

.2 *For a direct propulsion system with more than one machinery space*: The engine in the room with defect ventilation should be manually shutdown, if at least 40% propulsion power is still available after such a shutdown.

If only one machinery space for gas-fuelled engines is fitted and ventilation in one of the enclosed ducts around the gas pipes is lost, the master gas fuel and double block and bleed valves in that supply line should close automatically provided the other gas supply unit is ready to deliver.

5.6.8 If the gas supply is shut off due to activation of an automatic valve, the gas supply should not be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect should be placed at the operating station for the shut-off valves in the gas supply lines.

5.6.9 If a gas leak leading to a gas supply shutdown occurs, the gas fuel supply should not be operated until the leak has been found and dealt with. Instructions to this effect should be placed in a prominent position in the machinery space.

5.6.10 A signboard should be permanently fitted in the machinery space containing gas-fuelled engines stating that heavy lifting, implying danger of damage to the gas pipes, should not be done when the engine(s) is running on gas.

Table 1 – Monitoring of gas supply system to engines

Parameter	**Alarm**	**Automatic shutdown of main tank valve**	**Automatic shutdown of gas supply to machinery space containing gas-fuelled engines**	**Comment**
Gas detection in tank room above 20% LEL	X			
Gas detection on two detectors [1] in tank room above 40% LEL	X	X		
Fire detection in tank room	X	X		
Bilge well high level tank room	X			
Bilge well low temperature in tank room	X	X		
Gas detection in duct between tank and machinery space containing gas-fuelled engines above 20% LEL	X			
Gas detection on two detectors [1] in duct between tank and machinery space containing gas-fuelled engines above 40% LEL	X	X [2]		
Gas detection in compressor room above 20% LEL	X			
Gas detection on two detectors[1] in compressor room above 40% LEL	X	X [2]		

Parameter	Alarm	Automatic shutdown of main tank valve	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comment
Gas detection in duct inside machinery space containing gas-fuelled engines above 30% LEL	X			If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection on two detectors[1)] in duct inside machinery space containing gas-fuelled engines above 40% LEL	X		X [3)]	If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection in machinery space containing gas-fuelled engines above 20% LEL	X			Gas detection only required for ESD protected machinery space
Gas detection on two detectors[1)] in machinery space containing gas-fuelled engines above 40% LEL	X		X	Gas detection only required for ESD protected machinery space containing gas-fuelled engines. It should also disconnect non certified safe electrical equipment in machinery space containing gas-fuelled engines
Loss of ventilation in duct between tank and machinery space containing gas-fuelled engines [6)]	X		X [2) 4)]	
Loss of ventilation in duct inside machinery space containing gas-fuelled engines [6)]	X		X [3) 4)]	If double pipe fitted in machinery space containing gas-fuelled engines
Loss of ventilation in machinery space containing gas-fuelled engines	X		X	ESD protected machinery space containing gas-fuelled engines only
Fire detection in machinery space containing gas-fuelled engines	X		X	
Abnormal gas pressure in gas supply pipe	X		X [4)]	
Failure of valve control actuating medium	X		X[5)]	Time delayed as found necessary
Automatic shutdown of engine (engine failure)	X		X[5)]	
Emergency shutdown of engine manually released	X		X	

1) Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self monitoring type the installation of a single gas detector can be permitted.
2) If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.
3) If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.
4) This parameter is not to lead to shutdown of gas supply for single fuel gas engines, only for dual fuel engines.
5) Only double block and bleed valves to close.
6) If the duct is protected by inert gas (see 2.7.1) then loss of inert gas overpressure is to lead to the same actions as given in this table.

CHAPTER 6

COMPRESSORS AND GAS ENGINES

6.1 Gas compressors

6.1.1 The fuel gas compressor should be fitted with accessories and instrumentation necessary for efficient and reliable function.

6.1.2 The gas compressor and fuel gas supply should be arranged for manual remote emergency stop from the following locations:

.1 cargo control room (relevant for cargo ships only);
.2 navigation bridge;
.3 engine control room; and
.4 fire control station.

6.2 Gas engine design general

6.2.1 The last gas valve prior to the gas engine should be controlled by the engine control system or by the engine gas demand.

All gas engine components, gas engine systems and gas engine subsystems should be designed to:

.1 exclude any explosion at all possible situations; or

.2 to allow explosions without detrimental effect and to discharge to a safe location. The explosion event should not interrupt the safe operation of the engine unless other safety measures allow the shutdown of the affected engine.

6.2.1.1 When gas is supplied in a mixture with air through a common manifold, sufficient flame arrestors should be installed before each cylinder head. The mixture inlet system should be designed to withstand explosions of mixture by means of:

.1 explosion relief venting to prevent excessive explosion pressures. It should be ensured that the explosion relief venting is installed in a way that it discharges to a safe location; or

.2 documentation demonstrating that the mixture inlet system has sufficient strength to contain the worst case explosion.

6.2.1.2 The exhaust system should be designed to withstand explosions of unburned mixture by means of:

.1 explosion relief venting to prevent excessive explosion pressures. It should be ensured that the explosion relief venting is installed such that they discharge to a safe location; or

.2 documentation showing that the exhaust system has sufficient strength to contain the worst case explosion.

6.2.1.3 The crankcase of gas engines should be provided with:

.1 crankcase explosion relief valves of a suitable type with sufficient relief area. The relief valves should be installed in way of each crank throw and should be arranged or provided with means to ensure that discharge from them is so directed as to minimize the possibility of injury to personnel. Refer to SOLAS regulations II-1/27 and 47.2; or

.2 documentation showing that the crankcase has sufficient strength to contain the worst case explosion.

6.2.1.4 It should be ensured that the explosion of unburned mixture within the exhaust system or the crankcase or the explosion of mixture within the mixture inlet is allowed without detrimental effect.

6.2.2 The design of piping on gas engines should follow the requirements in chapter 2.6 "System configuration" and chapter 2.7 "Gas supply system in gas machinery spaces".

6.2.3 The combustion of the gas mixture should be monitored. This can be achieved by monitoring of the exhaust gas or combustion chamber temperature.

6.2.4 The exhaust pipes of gas-fuelled engines should not be connected to the exhaust pipes of other engines or systems.

6.3 Requirements dual fuel engines

6.3.1 Start and normal stop should be on oil fuel only. Gas injection should not be possible without a corresponding pilot oil injection. The amount of pilot fuel fed to each cylinder should be sufficient to ensure a positive ignition of the gas mixture.

6.3.2 In case of shut-off of the gas fuel supply, the engines should be capable of continuous operation by oil fuel only.

6.3.3 Changeover to and from gas fuel operation should only be possible at a power level and under conditions where it can be done with acceptable reliability as demonstrated through testing. On power reduction the changeover to oil fuel is to be automatic. The changeover process itself from and to gas operation should be automatic. Manual interruption should be possible in all cases.

6.3.4 On normal stop as well as emergency shutdown, gas fuel supply should be shut off not later than simultaneously with the oil fuel. It should not be possible to shut off the supply pilot fuel without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

6.4 Requirements gas-only engines

6.4.1 The starting sequence should be such that fuel gas is not admitted to the cylinders until ignition is activated and the engine has reached an engine and application specific minimum rotational speed.

6.4.2 If ignition has not been detected by the engine monitoring system within an engine specific time after opening of the gas supply valve the gas supply valve should be automatically shut off and the starting sequence terminated. It should be ensured by any mean that any unburned gas mixture is flushed away from the exhaust system.

6.4.3 On normal stop as well as emergency shutdown, gas fuel supply should be shut off not later than simultaneously with the ignition. It should not be possible to shut off the ignition without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

6.4.4 For constant speed engines the shut down sequence should be such that the engine gas supply valve closes at idle speed and that the ignition system is kept active until the engine is down to standstill.

CHAPTER 7

MANUFACTURE, WORKMANSHIP AND TESTING

7.1 General

The manufacture, testing, inspection and documentation should be in accordance with recognized standards and the specific requirements given in these Guidelines.

7.2 Gas tanks

Tests related to welding and tank testing should be in accordance with the IGC Code, sections 4.10 and 4.11.

7.3 Gas piping systems

7.3.1 The requirements for testing should apply to gas piping inside and outside the gas tanks. However, relaxation from these requirements may be accepted for piping inside gas tanks and open-ended piping.

7.3.2 Welding procedure tests should be required for gas piping and should be similar to those required for gas tanks in the IGC Code, paragraph 6.3.3. Unless otherwise especially agreed with the Administration, the test requirements should be in accordance with 7.3.3 below.

7.3.3 Test requirements:

.1 Tensile tests: Generally, tensile strength should not be less than the specified minimum tensile strength for the appropriate parent materials. The Administration may also require that the transverse weld tensile strength should not be less than the specified tensile strength for the weld metal, where the weld metal has a lower tensile strength than that of the parent metal. In every case, the position of fracture should be reported for information.

.2 Bend tests: No fracture should be acceptable after a 180° bend over a former of a diameter four times the thickness of the test piece, unless otherwise specially required or agreed with the Administration.

.3 Charpy V-notch impact tests: Charpy tests should be conducted at the temperature prescribed for the base material being joined. The results of the weld impact tests, minimum average energy (*E*), should be no less than 27 J. The weld metal requirements for sub-size specimens and singe energy values should be in accordance with the IGC Code paragraph 6.1.4. The results of fusion line and heat affected zone impact tests should show a minimum average energy (*E*) in accordance with the transverse or longitudinal requirements of the base material, whichever applicable, and for sub-size specimens, the minimum average energy (*E*) should be in accordance with the IGC Code, paragraph 6.1.4. If the material thickness does not permit machining either full-sized or standard sub-size specimens, the testing procedure and acceptance standards should be in accordance with recognized standards.

Impact testing is not required for piping with thickness less than 6 mm.

7.3.4 In addition to normal controls before and during the welding and to the visual inspection of the finished welds, the following tests should be required:

.1 For butt welded joints for piping systems with design temperatures lower than -10°C and with inside diameters of more than 75 mm or wall thicknesses greater than 10 mm, 100% radiographic testing should be required.

.2 When such butt welded joints of piping sections are made by automatic welding processes in the pipe fabrication shop, upon special approval, the extent of radiographic inspection may be progressively reduced but in no case to less than 10% of the joints. If defects are revealed the extent of examination should be increased to 100% and shall include inspection of previously accepted welds. This special approval should only be granted if well-documented quality assurance procedures and records are available to enable the Administration to assess the ability of the manufacturer to produce satisfactory welds consistently.

.3 For other butt welded joints of pipes, spot radiographic tests or other non-destructive tests should be carried out at the discretion of the Administration depending upon service, position and materials. In general, at least 10% of butt welded joints of pipes should be radiographed.

Butt welded joints of high-pressure gas pipes and gas supply pipes in ESD-protected machinery spaces should be subjected to 100% radiographic testing.

The radiographs should be assessed according to a recognized standard[17].

7.3.5 After assembly, all gas piping should be subjected to a hydrostatic test to at least 1.5 times the design pressure. However, when piping systems or parts of systems are completely manufactured and equipped with all fittings, the hydrostatic test may be conducted prior to installation aboard ship. Joints welded on board should be hydrostatically tested to at least 1.5 times the design pressure. Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, proposals for alternative testing fluids or testing methods should be submitted for approval.

7.3.6 After assembly on board, each gas piping system should be subjected to a leak test using air, halides or other suitable medium.

7.3.7 All gas piping systems including valves, fittings and associated equipment for handling gas should be tested under normal operating condition before set into normal operation.

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17 Refer to ISO 5817:2003, Arc-welded joints in steel – Guidance on quality levels for imperfections, and should at least meet the requirements for quality level B.

7.4 Ducting

If the gas piping duct contains high-pressure pipes the ducting should be pressure tested to at least 10 bar.

7.5 Valves

Each size and each type of valve intended to be used at a working temperature below -55°C should be prototype tested as follows. It should be subjected to a tightness test at the minimum design temperature or lower and to a pressure not lower than the design pressure for the valves. During the test, the good operation of the valve should be ascertained.

7.6 Expansion bellows

7.6.1 The following prototype tests should be performed on each type of expansion bellows intended for use in gas piping, primarily on those used outside the gas tank:

.1 An overpressure test. A type element of the bellows, not pre-compressed, should be pressure tested to a pressure not less than 5 times the design pressure without bursting. The duration of the test should not be less than 5 min.

.2 A pressure test on a type expansion joint complete with all the accessories (flanges, stays, articulations, etc.) at twice the design pressure at the extreme displacement conditions recommended by the manufacturer. No permanent deformations should be allowed. Depending on materials the test may be required to be performed at the minimum design temperature.

.3 A cyclic test (thermal movements). The test should be performed on a complete expansion joint, which is to successfully withstand at least as many cycles, under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement, as it will encounter in actual service. Testing at room temperature, when conservative, is permitted.

.4 A cyclic fatigue test (ship deformation). The test should be performed on a complete expansion joint, without internal pressure, by simulating the bellow movement corresponding to a compensated pipe length for at least 2×10^6 cycles at a frequency not higher than 5 Hz. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.

7.6.2 The Administration may waive performance of the tests specified in 7.6.1, provided that complete documentation is supplied to establish the suitability of the expansion joints to withstand the expected working conditions. When the maximum internal pressure exceeds 1 bar, this documentation should include sufficient tests data to justify the design method used, with particular reference to correlation between calculation and test results.

CHAPTER 8

OPERATIONAL AND TRAINING REQUIREMENTS

8.1 Operational requirement

8.1.1 The whole operational crew of a gas-fuelled cargo and a passenger ship should have necessary training in gas-related safety, operation and maintenance prior to the commencement of work on board.

8.1.2 Additionally, crew members with a direct responsibility for the operation of gas-related equipment on board should receive special training. The company should document that the personnel have acquired the necessary knowledge and that this knowledge is maintained at all times.

8.1.3 Gas-related emergency exercises should be conducted at regular intervals. Safety and response systems for the handling of defined hazards and accidents should be reviewed and tested.

8.1.4 A training manual should be developed and a training programme and exercises should be specially designed for each individual vessel and its gas installations.

8.2 Gas-related training

8.2.1 *Training in general*

The training on gas-fuelled ships is divided into the following categories:

.1 category A: Basic training for the basic safety crew;
.2 category B: Supplementary training for deck officers; and
.3 category C: Supplementary training for engineer officers.

8.2.1.1 *Category A training*

.1 The goal of the category A training should provide the basic safety crew with a basic understanding of the gas in question as a fuel, the technical properties of liquid and compressed gas, explosion limits, ignition sources, risk reducing and consequence reducing measures, and the rules and procedures that must be followed during normal operation and in emergency situations.

.2 The general basic training required for the basic safety crew is based on the assumption that the crew does not have any prior knowledge of gas, gas engines and gas systems. The instructors should include one or more of the suppliers of the technical gas equipment or gas systems, alternatively other specialists with in-depth knowledge of the gas in question and the technical gas systems that are installed on board.

.3 The training should consist of both theoretical and practical exercises that involve gas and the relevant systems, as well as personal protection while handling liquid and compressed gas. Practical extinguishing of gas fires should form part of the training, and should take place at an approved safety centre.

8.2.1.2 *Categories B and C training*

.1 Deck and engineer officers should have gas training beyond the general basic training. Category B and category C training should be divided technically between deck and engineer officers. The company's training manager and the master should determine what comes under deck operations and what comes under engineering.

.2 Those ordinary crew members who are to participate in the actual bunkering work, as well as gas purging, or are to perform work on gas engines or gas installations, etc., should participate in all or parts of the training for category B/C. The company and the master are responsible for arranging such training based on an evaluation of the concerned crew member's job instructions/area of responsibility on board.

.3 The instructors used for such supplementary training should be the same as outlined for category A.

.4 All gas-related systems on board should be reviewed. The ship's maintenance manual, gas supply system manual and manual for electrical equipment in explosion hazardous spaces and zones should be used as a basis for this part of the training.

.5 This regulation should be regularly reviewed by the company and onboard senior management team as part of the SMS system. Risk analysis should be emphasized, and any risk analysis and sub-analyses performed should be available to course participants during training.

.6 If the ship's own crew will be performing technical maintenance of gas equipment, the training for this type of work should be documented.

.7 The master and the chief engineer officer should give the basic safety crew on board their final clearance prior to the entry into service of the ship. The clearance document should only apply to gas-related training, and it should be signed by both the master/chief engineer officer and the course participant. The clearance document for gas-related training may be integrated in the ship's general training programme, but it should be clearly evident what is regarded as gas-related training and what is regarded as other training.

.8 The training requirements related to the gas system should be evaluated in the same manner as other training requirements on board at least once a year. The training plan should be evaluated at regular intervals.

8.3 Maintenance

8.3.1 A special maintenance manual should be prepared for the gas supply system on board.

8.3.2 The manual should include maintenance procedures for all technical gas-related installations, and should comply with the recommendations of the suppliers of the equipment. The intervals for, and the extent of, the replacement/approval of gas valves should be established. The maintenance procedure should specify who is qualified to carry out maintenance.

8.3.3 A special maintenance manual should be prepared for electrical equipment that is installed in explosion hazardous spaces and areas. The inspection and maintenance of electrical installations in explosion hazardous spaces should be performed in accordance with a recognized standard.[18]

8.3.4 Any personnel that should carry out inspections and maintenance of electrical installations in explosion hazardous spaces should be qualified pursuant to IEC 60079-17, item 4.2.

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[18] Refer to IEC 60079-17:2007 Explosive atmospheres – Part 17: Electrical installations inspection and maintenance.

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