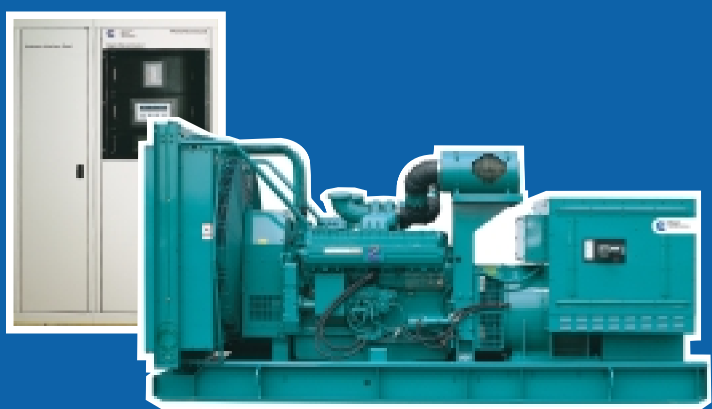
Cummins Power Generation

Application and Installation Guide for Generator Sets



Application and Installation Guide for Generator Sets

Published and Distributed by:
Cummins Power Generation Limited
Manston Park, Columbus Avenue
Manston, Ramsgate
Kent CT12 5BF, UK
Tel: +44 (0)1843 255000
Fax: +44 (0)1843 255902
Email: cpg.info@cummins.com
www.cumminspower.com
www.cummins.com

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Section I

Guide to (British) Standards

The British standard can be confusing on first sight but is comparatively simple:–

BS EN 60439-1:1994, Low-voltage switchgear and controlgear assemblies – Part 1 – Specification for type-tested and partially type-tested assemblies.

BS	British Standard. (A National Standard).
EN	A harmonised European standard.
60439	Standard number.
-1	Part number (of a multi-part standard).
1994	Date of promulgation (issue) of standard in that particular country.

Low-voltage switchgear and controlgear assemblies.

Description of equipment to which the standard, or family of standards in this case, applies.

- Part 1 – Specification for type-tested and partially type-tested assemblies.

Description of what this particular part of the family of standards applies.

A standard that is prefixed BS EN is a European standard that has been transposed into a National (British) Standard.

Dates.

The date (Year) incorporated in the full title of the standard is important. A standard with the same number but later date supersedes a similarly numbered standard with an earlier date.

BS EN 60439-1:1994, Low-voltage switchgear and controlgear assemblies – Part 1 – Specification for type-tested and partially type-tested assemblies, has been superseded by BS EN 60439-1:1999.

An ISO standard is an International Standard.

The number of the standard (reference number) is retained throughout Europe. For example, BS EN 292: Safety of Machinery. Basic Concepts, Principles for Design, has a German equivalent – DIN EN 292.

The International Standard IEC 204; The Electrical Equipment of Industrial Machinery, produced by the International Electrotechnical Commission, was examined by the CENELEC committee who made a few alterations to the text and republished the title under the reference EN 60204. It was then published throughout Europe with national references. In the UK it has become BS EN 60204: Safety of Machinery. Electrical Equipment of Machines and in Germany it is DIN EN 60204. The EN designation shows that it is a harmonised European standard.

Some British standards, although not having the same reference number as an ISO standard, are identical and each British Standard that is identical to an ISO will have a statement to that effect in its National Foreword. An example is BS 7698:Part 1:1993, this is identical to ISO 8528-1:1993.

Technical Harmonisation

National standards, unlike legislation, can be technically harmonised throughout Europe. The European Commission mandates three competent organisations to produce standards and normally mandates standards in conjunction with the secretariat of the EFTA. Each body is responsible for specific standards.

1. CEN (Comité Européen de Normalisation) is the European body for standardisation producing general standards.
2. CENELEC (Comité Européen de Normalisation Electrotechnique) produces electrical standards.
3. ETSI (European Telecommunication Standards Institute) produces telecommunication standards.

Electrical Equipment	
1. The Electricity Supply Regulations 1988, Statutory Instrument 1988 No. 1057. As amended by:– The Electricity Supply (Amendment) Regulations 1992 Statutory Instrument 1992 No. 2961.	6. IEC 60479 Effects of current passing through the human body.
	7. BS 7671:2000 IEE Regulations (16th Edition).
	8. BS 159:1992 Specification for high-voltage busbars and busbar connections.
2. Specification for distribution assemblies for reduced low voltage electricity supplies for construction and building sites. BS 4363:1998	9. BS EN 60298:1996, IEC 60298:1990 A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV. BS EN 60439:1999, IEC 60439:1999 Specification for low-voltage switchgear and controlgear assemblies. Partially type-tested assemblies. BS 7354:1990 Code of practice for design of high-voltage open-terminal stations.
3. CP 321/102 Installation and Maintenance of Electrical Machines	
4. Electricity Association Recommendations G5/4 Planning levels for harmonic voltage distortion & the connection of non-linear equipment to transmission systems & distribution networks in the United Kingdom G59/1 Recommendations for the connection of embedded generating plant to the Public Electricity Suppliers distribution systems. Amendment 1, 1992 and Amendment 2, 1995 incorporated.	10. BS 2757:1986, IEC 60085:1984 Method for determining the thermal classification of electrical insulation.
	11. BS EN 60947-1-6:2001 Specification for low-voltage switchgear and controlgear. Contactors and motor-starters. Electromechanical contactors and motor-starters.
5. BS 4999 General requirements for rotating electrical machines. BS 5000 Specification for rotating electrical machines of particular types or for particular applications. BS 7698, ISO 8528 Reciprocating internal combustion engine driven alternating current generating sets. Parts 1 to 10 and part 12.	

Mechanical Equipment	
1. BS 4278:1984 Specification for eyebolts for lifting purposes	5. BS 7698: Part 9:1996, ISO 8528-9:1995 Reciprocating internal combustion engine driven alternating current generating sets – Part 9. Measurement and evaluation of mechanical vibrations.
2. BS 476-7:1997 Fire tests on building materials and structures. Method of test to determine the classification of the surface spread of flame of products.	6. BS 5117 Testing corrosion inhibiting, engine coolant concentrate ('antifreeze'). Parts 0, 1.1 to 1.5, 2.1 to 2.6.
3. BS 799-5:1987 Oil burning equipment. Specification for oil storage tanks	7. BS 5514, ISO 3046 Reciprocating internal combustion engines. Performance. Parts 1, 3, 4 and 7.
4. BS 2869: Part 1:1988 Fuel oils for non-marine use. Specification for automotive diesel fuel (class A1). And:– BS 2869: Part 2:1988 Fuel oils for non-marine use. Specification for fuel oil for agricultural and industrial engines and burners (classes A2, C1, C2, D, E, F, G and H).	

General/Safety	
1. Health and Safety at Work Act.	11. 2000/14/EC. The Noise Emission in the Environment by Equipment for use Outdoors Regulations 2001. (SI 2001 No. 1701). The implementation in the UK of EU directive 2000/14/EC Noise emission in the environment by equipment for use outdoors.
2. The Control of Substances Hazardous to Health Regulations 1999 (SI 1999 No. 437).	12. BS 7445 ISO 1996 Description and measurement of environmental noise, sections –1, –2 and –3.
3. Full title:– The Electricity at Work Regulations 1989 (SI 1989 No. 635).	13. BS EN 12601:2001 Reciprocating internal combustion engine driven generating sets. Safety
4. The Control of Pollution (Oil Storage) (England) Regulations 2001, (SI 2001 No. 2954). Also refer to the Environmental Agency Pollution Prevention Guidelines – Above Ground Oil Storage Tanks, document PPG 2.	14. 200/14/EC. The Noise Emission in the Environment by Equipment for use Outdoors Regulations 2001. (SI 2001 No. 1701). The implementation in the UK of EU directive 2000/14/EC Noise emission in the environment by equipment for use outdoors.
5. Management of Health and Safety at Work Regulations 1999 (SI 1999 No. 3242).	15. BS EN 61000-6-2:1999, IEC 61000-6-2:1999 Electromagnetic compatibility (EMC). Generic standards. Immunity for industrial environments.
6. Electromagnetic Compatibility Regulations 1992 (SI 1992 No. 2372), the Electromagnetic Compatibility (Amendment) Regulations 1994 (SI 1994 No. 3080) and the Electromagnetic Compatibility (Amendment) Regulations 1995 (SI 1995 No. 3180).	16. BS EN 60034 Rotating electrical machines.
7. Electrical Equipment (Safety) Regulations 1994 (SI 1994 No. 3260).	17. IGE/UP3 Gas fuelled spark ignition and dual fuel engines. IGE Communication 1621. This provides guidance on the installation of gas fuelled spark ignition and dual-fuel engines of both the reciprocating and rotary type, with stationary or portable, for both continuous and standby duties.
8. Machinery Directive (98/37/EC), promulgated as the Supply of Machinery (Safety) Regulations 1992 (SI 1992 No. 3073) (SMSR), and the Supply of Machinery (Safety) (Amendment) Regulations 1994 (SI 1994 No. 2063).	
9. 2000/14/EC Noise emission in the environment by equipment for use outdoors, promulgated as the Noise Emission in the Environment by Equipment for use Outdoors Regulations 2001. (SI 2001 No. 1701).	
10. EN 50081–2: Electromagnetic compatibility. Generic immunity standard. Part 2, Industrial environment.	

Directives.

A European Directive in legislation enacted in EU law that instructs member states to incorporated into laws of the individual countries.

The individual countries' governments produce Statutory Instruments that are legally binding within the country.

Not all EU legislation is translated into a British Standard. A European Directive is normally incorporated in the laws of the country.

For example: -

Machinery Directive 98/37/EC was promulgated as the Supply of Machinery (Safety) Regulations 1992 (SI 1992 No. 3073) as amended by the Supply of Machinery (Safety) (Amendment) Regulations 1994 (SI 1994 No. 2063).

Directive 2000/14/EC - Noise emission in the environment by equipment for use outdoors – was promulgated as the Statutory Instrument 2001 No. 1701 - Noise Emission in the Environment by Equipment for use Outdoors Regulations 2001.

Updating of Directives.

As Directives are amended, further Directives are issued, documenting those amendments. If too many amendments are produced, a 'new' directive is issued incorporating or consolidating all amendments.

For example, Directive 98/37/EC is a consolidation of the original Machinery Directive (89/392/EEC) and its amending Directives (91/368/EEC, 93/44/EEC and 93/68/EEC).

There can be a difference in the date of the Directive and the SI; for example Directive 2000/14/EC and Statutory Instrument 2001 No. 1701, this is due to the time required to pass a Directive through the various committee stages or to make it a statute.

Definitions.

Statutory Instruments.

Usually referred to as a set of "Regulations". Legislation that refers to a specific topic or process and is thus "specialist" in nature. Statutory Instruments are initiated by specialist bodies with expert knowledge of the subject being dealt with. Once written, they go through the same various parliamentary stages as Statutes and they are given the Royal Assent to become Statutory Law. Statutory Instruments have equal authority to Statutes hence also take precedence over all other forms of UK law.

Statute.

Often referred to as an "Act". Legislation which is initiated by Parliament and after going through various parliamentary stages, is given the Royal Assent. The statute thus becomes Statutory Law and takes precedence over all other forms of UK law.

Some American and Canadian Standards relevant to Power Generation

The Cummins PowerCommand™ Control System meets or exceeds the requirements of the following codes and standards: –

UL 508 – Category NIWT7 for US and Canadian usage.

UL 891 – For US and Canadian usage.

UL 489 – Overcurrent Performance verified by U.L.

ISO 8528-4 – Control systems for reciprocating engine-driven generator sets.

ISO 7637 Pulses # 2b, 4 – DC supply surge voltage test.

Canadian Standards – 282-MI

CSA C22.2, No. 14 – M91 for Industrial Control Equipment.

NFPA 70 – US National Electrical Code (suitable for use in emergency or standby applications).

NFPA 110 – Emergency Power Systems. Meets all requirements for Level 1 Systems.

NFPA 99 – Standard for Health Care Facilities.

AS3000 SAA – Wiring Rules.

AS3009 – Emergency Power Supplies.

AS3010.1 – Electrical supply by Generator Sets.

Mil Std 461 – Electromagnetic Emission and Susceptibility Requirements.

Mil Std 202C Method 101 – Salt Fog Test.

IEC 801.2 – Electrostatic Discharge Test.

IEC 801.3 – Radiated Susceptibility.

IEC 801.5 – Radiated Emissions

These standards define the ability of the entire control system to withstand various electromagnetic interference levels and not interfere with the operation of other devices.

IEC 801.4 – Electrically Fast Transient.

IEC 801-5/IEEE 587 – Surge Immunity.

These tests demonstrate that the Control system is highly resistant to failure due to voltage surges.

EN50081-1 – Residential, Commercial, Light Industrial.

EN50081-2 – Industrial.

EN50082-1 – Residential, Commercial, Light Industrial.

EN50082-2 – Industrial.

ANSI C62.41 Surge withstand.

Regulations Governing Installations

Before purchasing a generating set, the advice of the local authority should be obtained with regard to the following requirements:–

Planning permission for the generator building regulations governing the following:–

- Storage of fuel, lubrication oil and coolant.
- Noise levels.
- Air pollution levels.
- Electrical earthing requirements.
- Electrical supply authority permission.

Failure to comply with the local authorities regulations may result in the generator being restricted in use or permission denied. This level of purchase should be installed correctly using the ‘best’ materials and good quality worksmanship using installation guides to ensure the generator is durable and reliable.

Specialist advice can be sought concerning any part of the building requirements, installation, commissioning, transportation, viability of the project or any information in this manual by contacting Cummins Power Generation Ltd.

Data compiled in this manual will be continuously improved and updated and therefore subject to change without notice, all rights are reserved.

World Electricity Supplies

Country	Frequency (Hz)	Supply Voltage Levels in Common Use (V)
Abu Dhabi (United Arab Emirates)	50	415/250
Afghanistan	50; 60	380/220; 220
Algeria	50	10 kV; 5.5 kV; 380/220; 220/127
Angola	50	380/220; 220
Antigua	60	400/230; 230
Argentina	50	13.2 kV; 6.88 kV; 390/225; 339/220: 220
Australia	50	22 kV; 11 kV; 6.6 kV; 440/250; 415/240; 240
Austria	50	20 kV; 10 kV; 5 kV; 380/220; 220
Bahamas	60	415/240; 240/120; 208/120; 120
Bahrain	50: 60	11 kV; 400/230: 380/220; 230; 220/110
Bangladesh	50	11 kV; 400/230; 230
Barbados	50	11 kV; 3.3 kV; 230/115; 200/115
Belgium	50	15 kV; 6 kV; 380/220; 2201127, 220
Belize	60	440/220; 220/110
Bermuda	60	4.16/2.4 kV; 240/120; 208/120
Bolivia	50; 60	230/115; 400/230/220/110
Botswana	50	380/220: 220
Brazil	50; 60	13.8 kV; 11.2 kV: 380/220,220/127
Brunei	50	415/230
Bulgaria	50	20 kV; 15 kV; 380/220; 220
Burma	50	11 kV; 6.6 kV; 400/230; 230
Burundi		
Cambodia (Khmer Republic)	50	380/220; 208/120; 120
Cameroon	50	15 kV; 320/220; 220
Canada	60	12.5/7.2 kV; 600/347; 240/120; 208/120; 600; 480; 240
Canary Islands	50	380/220; 230
Cape Verde Islands	50	380/220; 127/220
Cayman Islands	60	480/240; 480/227; 240/120; 208/120
Central African Republic	50	380/220
Chad	50	380/220; 220
China	50	380/220 50Hz
Chile	50	380/220; 220
Colombia	60	13.2 kV; 240/120; 120
Costa Rica	60	240/120; 120
Cuba	60	440/220; 220/110
Cyprus	50	11 kV; 415/240; 240
Czechoslovakia	50	22 kV; 15 kV; 6 kV; 3 kV; 380/220; 220
Dahomey	50	15 kV; 380/220; 220
Denmark	50	30 kV; 10 kV; 380/220; 220
Dominica (Windward Islands)	50	400/230
Dominican Republic	60	220/110; 110
Dubai (United Arab Emirates)	50	6.6 kV; 330/220; 220
Ecuador	60	240/120; 208/120; 220/127; 220/110
Egypt (United Arab Republic)	50	11 kV; 6.6 kV; 380/220; 220
Eire (Republic of Ireland)	50	10 kV; 380/220; 220
El Salvador	60	14.4 kV; 2.4 kV; 240/120
Ethiopia	50	380/220; 220
Faeroe Islands (Denmark)	50	380/220
Falkland Islands (UK)	50	415/230; 230
Fiji	50	11 kV; 415/240; 240
Finland	50	660/380; 500; 380/220; 220
France	50	20 kV; 15 kV; 380/220; 380; 220; 127
French Guiana	50	380/220
French Polynesia	60	220; 100
Gabon	50	380/220
Gambia	50	400/230; 230
Germany (BRD)	50	20 kV; 10 kV; 6 kV; 380/220; 220
Germany (DDR)	50	10 kV; 6 kV; 660/380; 380/220; 220/127; 220; 127
Ghana	50	440/250; 250
Gibraltar	50	415/240
Greece	50	22 kV; 20 kV; 15 kV; 6.6 kV; 380/220
Greenland	50	380/220
Grenada (Windward Islands)	50	400/230; 230
Guadeloupe	50; 60	20 kV; 380/220; 220
Guam (Mariana Islands)	60	13.8 kV; 4 kV; 480/277; 480: 240/120; 207/120
Guatemala	60	13.8 kV; 240/120
Guyana	50	220/110
Haiti	60	380/220; 230/115; 230; 220; 115
Honduras	60	220/110; 110
Hong Kong (and Kowloon)	50	11 kV; 346/200; 200
Hungary	50	20 kV; 10 kV; 380/220; 220
Iceland	50	380/220; 220
India	50; 25	22 kV; 11 kV; 440/250; 400/230; 460/230; 230
Indonesia	50	380/220; 2201127
Iran	50	20 kV; 11 kV; 400/231; 380/220; 220
Iraq	50	11 kV; 380/220; 220
Israel	50	22 kV; 12.6 kV; 6.3 kV; 400/230; 230
Italy	50	20 kV; 15 kV; 10 kV; 380/220; 220/127; 220
Ivory Coast	50	380/220; 220
Jamaica	50	4/2.3 kV; 220/110
Japan	50; 60	6.6 kV; 200/100; 22 kV; 6.6 kV; 210/105; 200/100; 100
Jordan	50	380/220; 220
Kenya	50	415/240; 240
Korea Republic (South)	60	200/100; 100
Kuwait	50	415/240; 240
Laos	50	380/220
Lebanon	50	380/220; 190/110; 220;110
Lesotho	50	380/220; 220
Liberia	60	12.5/7.2 kV; 416/240; 240/120; 208/120
Libyan Arab Republic	50	400/230; 220/127; 230;127
Luxembourg	50	20 kV; 15 kV; 380/220; 220
Macao	50	380/220; 220/110
Malagassy Republic (Madagascar)	50	5 kV; 380/220; 220/127
Malawi	50	400/230; 230
Malaysia (West)	50	415/240; 240
Mali	50	380/220; 220/127; 220; 127
Malta	50	415/240
Manila	60	20 kV; 6.24 kV; 3.6 kV; 240/120
Martinique	50	220/127; 127
Mauritania	50	380/220
Mauritius	50	400/230; 230
Mexico	60	13.8 kV; 13.2 kV; 480/277; 220/127; 220/120
Monaco	50	380/220; 220/127; 220; 127

World Electricity Supplies

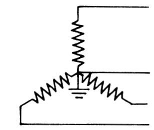
Country	Frequency (Hz)	Supply Voltage Levels in Common Use (V)
Montserrat	60	400/230; 230
Morocco	50	380/220; 220/127
Mozambique	50	380/220
Muscat and Oman	50	415/240; 240
Naura	50	415/240
Nepal	50	11 kV; 400/220; 220
Netherlands	50	10 kV; 3 kV; 400/230; 230
Netherlands Antilles	50; 60	380/220; 230/115; 220/127; 208/120
New Caledonia	50	220
New Zealand	50	11 kV; 415/240; 400/230; 440; 240; 230
Nicaragua	60	13.2 kV; 7.6 kV; 240/120
Niger	50	380/220; 220
Nigeria	50	15 kV; 11 kV; 400/230; 380/220; 230; 220
Norway	50	20 kV; 10 kV; 5 kV; 400/230; 230
Pakistan	50	400/230; 230
Panama	60	12 kV; 480/227; 240/120; 208/120
Papua New Guinea	50	22 kV; 11 kV; 415/240; 240
Paraguay	50	440/220; 380/220; 220
Peru	60	10 kV; 6 kV; 225
Philippines	60	13.8 kV; 4.16 kV; 2.4 kV; 220/110
Poland	50	15 kV; 6 kV; 380/220; 220
Portugal	50	15 kV; 5 kV; 400/230; 230
Portuguese Guinea	50	380/220
Puerto Rico	60	8.32 kV; 4.16 kV; 480; 240/120
Qatar	50	415/240; 240
Reunion	50	110/220
Romania	50	20 kV; 10 kV; 6 kV; 380/220; 220
Rwanda	50	15 kV; 6.6 kV; 380/220; 220

Country	Frequency (Hz)	Supply Voltage Levels in Common Use (V)
Sabah	50	415/240; 240
Sarawak (East Malaysia)	50	4151240; 240
Saudi Arabia	60	380/220; 220/127; 127
Senegal	50	220/127; 127
Seychelles	50	415/240
Sierra Leone	50	11 kV; 400/230; 230
Singapore	50	22 kV; 6.6 kV; 400/230; 230
Somali Republic	50	440/220; 220/110; 230: 220; 110
South Africa	50; 25	11 kV; 6.6 kV; 3.3 kV; 433/250; 400/230; 380/220; 500; 220
Southern Yemen (Aden)	50	400/230
Spain	50	15 kV; 11 kV; 400/230; 230/127; 220; 127
Spanish Sahara	50	380/220; 110; 127
Sri Lanka (Ceylon)	50	11 kV; 400/230; 230
St. Helena	50	11 kV; 415/240
St. Kitts Nevis Anguilla	50	400/230; 230
St. Lucia	50	11 kV; 415/240; 240
Saint Vincent	50	3.3 kV; 400/230; 230
Sudan	50	415/240; 240
Surinam	50; 60	230/115; 220/127; 220/110; 127; 115
Swaziland	50	11 kV; 400/230; 230
Sweden	50	20 kV; 10 kV; 6 kV; 400/230; 230
Switzerland	50	16 kV; 11 kV; 6 kV; 400/230; 230
Syrian Arab Republic	50	380/220; 200/115; 220; 115
Taiwan (Republic of China)		60 22.8 kV; 11.4 kV; 380/220; 220/110
Tanzania (Union Republic of)	50	11 kV; 400/230
Thailand	50	380/220; 220

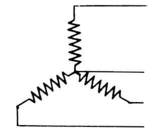
Country	Frequency (Hz)	Supply Voltage Levels in Common Use (V)
Togo	50	20 kV; 5.5 kV; 380/220; 220
Tonga	50	11 kV; 6.6 kV; 415/240; 240; 210
Trinidad and Tobago	60	12 kV; 400/230; 230/115
Tunisia	50	15 kV; 10 kV; 380/220; 220
Turkey	50	15 kV; 6.3 kV; 380/220; 220
Uganda	50	11 kV; 415/240; 240
United Kingdom	50	22 kV; 11 kV; 6.6 kV; 3.3 kV; 400/230; 380/220; 240; 230; 220
Upper-Yolta	50	380/220; 220
Uruguay	50	15 kV; 6 kV; 220
USA	60	480/277; 208/120; 240/120
USSR	50	380/230; 220/127 and higher voltages
Venezuela	60	13.8 kV; 12.47 kV; 4.8 kV; 4.16 kV; 2.4 kV; 240/120; 208/120
Vietnam (Republic of)	50	15 kV; 380/220; 208/120; 220; 120
Virgin Islands (UK)	60	208; 120
Virgin Islands (US)	60	110/220
Western Samoa	50	415/240
Yemen, Democratic (PDR)	50	440/250; 250
Yugoslavia	50	10 kV; 6.6 kV; 380/220; 220
Zaire (Republic of)	50	380/220; 220
Zambia	50	400/230; 230
Zimbabwe	50	11 kV; 390/225; 225

Table 1 World Electricity Supplies

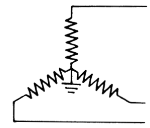
Supply Voltages



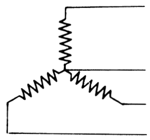
A THREE PHASE STAR: FOUR WIRE: EARTHED NEUTRAL — 50 Hz, 550/320, 440/254, 415/240, 346/200, 390/225, 200/115, 190/110; 50 Hz or 60 Hz, 440/230, 380/220, 220/127, 208/120; 60 Hz only, 460/265, 480/277



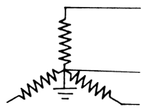
B THREE PHASE STAR: THREE WIRE: — 50 Hz, 380/220; 60 Hz, 220/127, 416/240



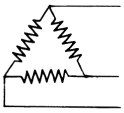
C THREE PHASE STAR: THREE WIRE: EARTHED NEUTRAL POINT — 60Hz, 480/277



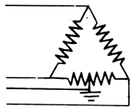
D THREE PHASE STAR: FOUR WIRE: NON EARTHED NEUTRAL: — 50 Hz, 380/220; 60 Hz, 208/120



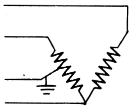
E TWO PHASE STAR: THREE WIRE: EARTHED NEUTRAL: — 50 Hz, 220/127; 380/220, 400/230, 415/240



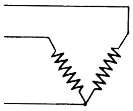
F THREE PHASE DELTA: THREE WIRE: — 50 Hz, 220; 60 Hz, 230,240,480, 575



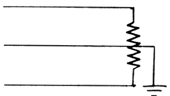
G THREE PHASE DELTA: FOUR WIRE: EARTHED MID POINT OF PHASE: — 50 Hz, 220/110; 440/220; 50/60 Hz, 230/115; 60 Hz, 240/120,240/210, 480/240



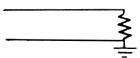
H THREE PHASE OPEN DELTA: FOUR WIRE: EARTHED MID POINT OF PHASE: — 50 Hz, 200/100; 230/115; 60 Hz, 210/105, 220/110, 240/120



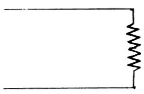
J THREE PHASE OPEN DELTA: FOUR WIRE: EARTH JUNCTION OF PHASE: — 50 Hz, 200



K SINGLE PHASE: THREE WIRE: EARTHED MID POINT: — 50 or 60 Hz, 200/100, 220/110; 230/115; 60 Hz, 210/105, 240/120



L SINGLE PHASE: TWO WIRE: EARTHED END OF PHASE: — 50 Hz, 200, 225, 250; 50 or 60 Hz, 100, 110, 115, 120, 127, 220, 230, 240



M SINGLE PHASE: TWO WIRE: EARTHED NEUTRAL: — 60 Hz, 120

Line Volts A-B B-C C-A	Std. 4 Wire Line to Neutral A-N B-N C-N	Line Volts A-B B-C C-A	Std. 4 Wire Line to Neutral A-N B-N C-N
180	104	370	213
190	110	380	220
200	110	390	225
208	120	400	230
210	121	410	237
220	127	415	240
230	133	420	248
240	139	430	252
250	144	440	254
		450	260
340	196	460	266
350	202		
360	208	500	288

Equivalents and Formulae

Equivalents

1 horsepower = 746watts
1 horsepower = 0.746kW
1 horsepower = 33,000ft lb/min

1 kW = 1 000watts
1 kW = 1.3415hp
1 kW = 56.8ft lb/min

ft lb/min
1 horsepower = 550ft lb/sec
1 horsepower = 2546Btu/hr
1 horsepower = 42.4Btu/min

1 kW = 738ft lb/sec
1 kW = 3412Btu/hr

1 Btu = 9340in lb
1 Btu = 778.3ft lb
1 Btu =.0002930kWhr
1 Btu = 1.05506kJ

1ft lb = 0.001284Btu
1 kWhr = 3413Btu

1 Btu/min = 17.57watts
1 Btu/min = 0.0176kW
1 Btu/min = 0.0236hp
1 Btu/hr = 0.293watts

1 ft lb = 1.35582Nm
1 ft lb/sec = 0.001355kW
1 ft lb/sec = 0.001818hp

1 therm = 100,000Btu

12,000Btu = 1 Ton (air conditioning)

Formulae

Brake Mean Effective Pressure (BMEP)

$$\text{BMEP} = \frac{792{,}000 \times \text{BHP}}{\text{rpm} \times \text{cubic inch displacement}} \quad \text{(for 4-cycle)}$$

Brake Horsepower (BHP)

$$\text{BHP} = \frac{\text{BMEP} \times \text{cubic inch displacement} \times \text{rpm}}{792{,}000} \quad \text{(for 4-cycle)}$$

Torque

$$\text{Torque (ft lb)} = \frac{5250 \times \text{BHP}}{\text{rpm}}$$

Temperature

$$\text{Temp. (°C)} = \frac{(\text{°F} - 32)}{1.8} \qquad \text{°F} = (\text{°C} \times 1.8) + 32$$

Power Factor & kVA

$$\text{PF} = \frac{\text{kW}}{\text{kVA}} \qquad \text{KVA} = \frac{\text{kW}}{\text{PF}}$$

Formulae for Obtaining kW, kVA, Reactive kVA, BHP and Amperes

To Obtain:		
Single Phase AC	Three Phase AC	Direct Current
KW = $\frac{V_{L-N} \times A \times PF}{1000}$	$\frac{kVA \times PF}{1000}$	$\frac{V \times A}{1000}$
KVA = $\frac{V_{L-N} \times A}{1000}$	$\frac{V_{L-L} \times A \times 1.732}{1000}$	
BHP (Output) = $\frac{V_{L-N} \times A \times \sqrt{\text{Gen. Eff.} \times PF}}{746 \times 1000}$	$\frac{1.73 \times \sqrt{V_{L-L}} \times A \times \text{Eff.} \times PF}{746 \times 1000}$	$\frac{V \times A \times \text{Gen. Eff.}}{746 \times 1000}$
BHP (Input) = $\frac{kW}{746 \times 1000}$	$\frac{kW}{746 \times 1000}$	
A (when BHP is known) = $\frac{BHP \times 746 \times 100}{V_{L-N} \times \text{Gen. Eff.} \times PF}$	$\frac{BHP \times 746 \times 100}{1.73 \times V_{L-L} \times \text{Gen. Eff.} \times PF}$	$\frac{BHP \times 746 \times 100}{V \times \text{Gen. Eff.}}$
A (when kW is known) = $\frac{KW \times 1000}{V_{L-N} \times PF}$	$\frac{kW \times 1000}{V_{L-L} \times PF \times 1.732}$	$\frac{kW \times 1000}{V}$
A (when KVA is known) = $\frac{KVA \times 1000}{V_{L-N}}$	$\frac{KVA \times 1000}{V_{L-L} \times 1.732}$	

Misc.

$$\text{Reactive kVA} = \sqrt{\text{kVA}^2 - \text{kW}^2}$$

$$\text{HZ} = \frac{\text{No. of poles} \times \text{RPM}}{120} \qquad \frac{\text{No. of poles} \times \text{RPM}}{120}$$

$$\text{HP} = \frac{\text{KW}}{0.746 \times \text{Gen Efficiency}} \qquad \frac{\text{KW}}{0.746 \times \text{Gen Efficiency}}$$

Where;-
kW = Kilowatts
V_{L-L} = Line to Line Voltage
A = Line Current
PF = Power Factor
HZ = Frequency
HP = Horse Power
V_{L-N} = Line to Neutral Voltage
V = Voltage

FORMULA FOR DETERMINING AMPS, HORSEPOWER, KILOWATTS AND kVA

TO FIND	DIRECT CURRENT	ALTERNATING CURRENT: SINGLE PHASE 2 WIRE	TWO PHASE 4 WIRE	THREE PHASE 4 WIRE
Amps when H.P. is known	$\frac{H.P. \times 746}{E \times Eff}$	$\frac{H.P. \times 746}{E \times Eff \times PF}$	$\frac{H.P. \times 746}{2 \times E \times Eff \times PF}$	$\frac{H.P. \times 746}{1.73 \times E \times Eff \times PF}$
Amps when kW is known	$\frac{kW \times 1000}{E}$	$\frac{kW \times 1000}{E \times PF}$	$\frac{kW \times 1000}{2 \times E \times PF}$	$\frac{kW \times 1000}{1.73 \times E \times PF}$
Amps when kVA is known		$\frac{kVA \times 1000}{E}$	$\frac{kVA \times 1000}{2 \times E}$	$\frac{kVA \times 1000}{1.73 \times E}$
Kilowatts	$\frac{I \times E}{1000}$	$\frac{I \times E \times PF}{1000}$	$\frac{I \times 2 \times E \times PF}{1000}$	$\frac{I \times 1.73 \times E \times PF}{1000}$
kVA		$\frac{I \times E}{1000}$	$\frac{I \times E \times 2}{1000}$	$\frac{I \times E \times 1.73}{1000}$
Horse Power	$\frac{I \times E \times Eff}{746}$	$\frac{I \times E \times Eff \times PF}{746}$	$\frac{I \times E \times 2 \times Eff \times PF}{746}$	$\frac{I \times E \times 1.73 \times Eff \times PF}{746}$

I = Amps
E = Line Volts
Eff = per Unit Efficiency
kW = Kilowatts
PF = Power Factor
kVA = Kilo-Volt-Amps
H.P. = Horse Power

NOTE:
Efficiency varies between about 86% for 25kVA to 93% for 1000kVA. Generally the larger the alternator, the greater its efficiency. The power factor for normal purposes should be taken as 0.85.

CONVERSION TABLES

CENTIMETRES — INCHES

cm		INCHES	cm		INCHES
2.54	1	0.3937	129.54	51	20.0787
5.08	2	0.7874	132.08	52	20.4724
7.62	3	1.1811	134.62	53	20.8661
10.16	4	1.5748	137.16	54	21.2598
12.70	5	1.9685	139.70	55	21.6535
15.24	6	2.3622	142.24	56	22.0472
17.78	7	2.7559	144.78	57	22.4409
20.32	8	3.1496	147.32	58	22.8346
22.86	9	3.5433	149.86	59	23.2283
25.40	10	3.9370	152.40	60	23.6220
27.94	11	4.3307	154.94	61	24.0157
30.48	12	4.7244	157.48	62	24.4094
33.02	13	5.1181	160.02	63	24.8031
35.56	14	5.5118	162.56	64	25.1969
38.10	15	5.9055	165.10	65	25.5906
40.64	16	6.2992	167.64	66	25.9843
43.18	17	6.6929	170.18	67	26.3780
45.72	18	7.0866	172.72	68	26.7717
48.26	19	7.4803	175.26	69	27.1654
50.80	20	7.8740	177.80	70	27.5591
53.34	21	8.2677	180.34	71	27.9528
55.88	22	8.6614	182.88	72	28.3465
58.42	23	9.0551	185.42	73	28.7402
60.96	24	9.4488	187.96	74	29.1339
63.50	25	9.8425	190.50	75	29.5276
66.04	26	10.2362	193.04	76	29.9213
68.58	27	10.6299	195.58	77	30.3150
71.12	28	11.0236	198.12	78	30.7087
73.66	29	11.4173	200.66	79	31.1024
76.20	30	11.8110	203.20	80	31.4961
78.74	31	12.2047	205.74	81	31.8898
81.28	32	12.5984	208.28	82	32.2835
83.82	33	12.9921	210.82	83	32.6772
86.36	34	13.3858	213.36	84	33.0709
88.90	35	13.7795	215.90	85	33.4646
91.44	36	14.1732	218.44	86	33.8583
93.98	37	14.5669	220.98	87	34.2520
96.52	38	14.9606	223.52	88	34.6457
99.06	39	15.3543	226.06	89	35.0394
102.60	40	15.7480	228.60	90	35.4331
104.14	41	16.1417	231.14	91	35.8268
106.68	42	16.5354	233.68	92	36.2205
109.22	43	16.9291	236.22	93	36.6142
111.76	44	17.3228	238.76	94	37.0079
114.30	45	17.7165	241.30	95	37.4016
116.84	46	18.1102	243.84	96	37.7953
119.38	47	18.5039	246.38	97	38.1890
121.92	48	18.8976	248.92	98	38.5827
124.46	49	19.2913	251.46	99	38.9764
127.00	50	19.6850	254.00	100	39.3701

METRES — FEET

METRES		FEET	METRES		FEET
0.3048	1	3.28084	15.5448	51	167.323
0.6096	2	6.562	15.8496	52	170.604
0.9144	3	9.843	16.1544	53	173.884
1.2192	4	13.123	16.4592	54	177.165
1.5240	5	16.404	16.7640	55	180.446
1.8288	6	19.685	17.0688	56	183.727
2.1336	7	22.966	17.3736	57	187.008
2.4384	8	26.247	17.6784	58	190.289
2.7432	9	29.528	17.9832	59	193.570
3.0480	10	32.808	18.2880	60	196.850
3.3528	11	36.089	18.5928	61	200.131
3.6576	12	39.370	18.8976	62	203.412
3.9624	13	42.651	19.2024	63	206.693
4.2672	14	45.932	19.5072	64	209.974
4.5720	15	49.213	19.8120	65	213.255
4.8768	16	52.493	20.1168	66	216.535
5.1816	17	55.774	20.4216	67	219.816
5.4864	18	59.055	20.7264	68	223.097
5.7912	19	62.336	21.0312	69	226.378
6.0960	20	65.617	21.3360	70	229.659
6.4408	21	68.898	21.6408	71	232.940
6.7056	22	72.178	21.9456	72	236.220
7.0104	23	75.459	22.2504	73	239.501
7.3152	24	78.740	22.5552	74	242.782
7.6200	25	82.021	22.8600	75	246.063
7.9248	26	85.302	23.1648	76	249.344
8.2296	27	88.583	23.4696	77	252.625
8.5344	28	91.863	23.7744	78	255.906
8.8392	29	95.144	24.0792	79	259.186
9.1440	30	98.425	24.3840	80	262.467
9.4488	31	101.706	24.6888	81	265.748
9.7536	32	104.987	24.9936	82	269.029
10.0584	33	108.268	25.2984	83	272.310
10.3632	34	111.549	25.6032	84	275.591
10.6680	35	114.829	25.9080	85	278.871
10.9728	36	118.110	26.2128	86	282.152
11.2776	37	121.391	26.5176	87	285.433
11.5824	38	124.672	26.8224	88	288.714
11.8872	39	127.953	27.1272	89	291.995
12.1920	40	131.234	27.4320	90	295.276
12.4968	41	134.514	27.7368	91	298.556
12.8016	42	137.795	28.0416	92	301.837
13.1064	43	141.076	28.3464	93	305.118
13.4112	44	144.357	28.6512	94	308.399
13.7160	45	147.638	28.9560	95	311.680
14.0208	46	150.919	29.2608	96	314.961
14.3256	47	154.199	29.5656	97	318.241
14.6304	48	157.480	29.8704	98	321.522
14.9352	49	160.761	30.1752	99	324.803
15.2400	50	164.042	30.4800	100	328.084

SQ. CENTIMETRES — SQ. INCHES

cm°		INCHES°	cm°		INCHES°
6.452	1	0.155	329.032	51	7.905
12.903	2	0.310	335.483	52	8.060
19.355	3	0.465	341.935	53	8.215
25.806	4	0.620	348.386	54	8.370
32.258	5	0.775	354.838	55	8.525
38.710	6	0.930	361.290	56	8.680
45.161	7	1.085	367.741	57	8.835
51.613	8	1.240	374.193	58	8.990
58.064	9	1.395	380.644	59	9.145
64.516	10	1.550	387.096	60	9.300
70.968	11	1.705	393.548	61	9.455
77.419	12	1.860	399.999	62	9.610
83.871	13	2.015	406.451	63	9.765
90.322	14	2.170	412.902	64	9.920
96.774	15	2.325	419.354	65	10.075
103.226	16	2.480	425.806	66	10.230
109.677	17	2.635	432.257	67	10.385
116.129	18	2.790	438.709	68	10.540
122.580	19	2.945	445.160	69	10.695
129.032	20	3.100	451.612	70	10.850
135.484	21	3.255	458.064	71	11.005
141.935	22	3.410	464.515	72	11.160
148.387	23	3.565	470.967	73	11.315
154.838	24	3.720	477.418	74	11.470
161.290	25	3.875	483.878	75	11.625
167.742	26	4.030	490.322	76	11.780
174.193	27	4.185	496.773	77	11.935
180.645	28	4.340	503.225	78	12.090
187.096	29	4.495	509.676	79	12.245
193.548	30	4.650	516.128	80	12.400
200.000	31	4.805	522.579	81	12.555
206.451	32	4.960	529.031	82	12.710
212.903	33	5.115	535.483	83	12.865
219.354	34	5.270	541.934	84	13.020
225.806	35	5.425	548.386	85	13.175
232.258	36	5.580	554.838	86	13.330
238.709	37	5.735	561.289	87	13.485
245.161	38	5.890	567.741	88	13.640
251.612	39	6.045	574.192	89	13.795
258.064	40	6.200	580.644	90	13.950
264.516	41	6.355	587.096	91	14.105
270.967	42	6.510	593.547	92	14.260
277.419	43	6.665	599.999	93	14.415
283.870	44	6.820	606.450	94	14.570
290.322	45	6.975	612.902	95	14.725
296.774	46	7.130	619.354	96	14.880
303.225	47	7.285	625.805	97	15.035
309.677	48	7.440	632.257	98	15.190
316.128	49	7.595	638.708	99	15.345
322.580	50	7.750	645.160	100	15.500

Tables – Conversions

Cummins Power Generation

TO CONVERT	INTO	MULTIPLY BY
Acres	Hectares (10,000 sq.m)	0.4047
Acres	Square feet	43560
Acres	Square metres	4047
Acres	Square miles	0.001562
Ampere turns	Gilberts	1.257
Atmospheres	Inches of water at 4°C	406.8
Atmospheres	Inches of mercury at 0°C	29.92
Atmospheres	Kilograms/sq.m.	10330
Atmospheres	Newtons/sq.m.	101,320
Atmospheres	Pounds/sq.inch	14.7
BTU	Joules	1054.8
Btu/min	Watts	17.57
Centigrade	Fahrenheit	(C×1.8)+32°
Centimetres	Feet	0.03281
Centimetres	Inches	0.3937
Centimetres	Metres	0.01
Circular mils.	Sq. centimetres	5.067÷1000000
Circular mils.	Sq. inches	0.785÷1000000
Cubic centimetres	Cubic feet	35.31÷1000000
Cubic centimetres	Cubic inches	0.06102
Cubic centimetres	Cubic metres	1÷1000000
Cubic feet	Cubic centimetres	28320
Cubic feet	Cubic inches	1728
Cubic feet	Cubic metres	0.02832
Cubic feet	Litres	28.32
Cubic feet/minute	Cubic metres/hour	1.698
Cubic feet/minute	Litres/second	0.4717
Cubic inches	Cubic centimetres	16.387
Cubic inches	Cubic feet	0.5787÷1000
Cubic inches	Cubic metres	0.0164÷1000
Cubic metres	Cubic centimetres	1000000
Cubic metres	Cubic feet	35.31
Cubic metres	Cubic inches	61020
Cubic metres	Cubic yards	1.308
Cubic yards	Cubic metres	0.7646
Degrees (angle)	Radians	0.01745
Dynes	Pounds (force)	2.248÷1000000
Dynes	Poundals (force)	72.33÷1000000
Dynes	Newtons	10÷1000000
Dynes/sq.cm.	Newtons/square metre	0.1
Dynes/sq.cm.	Pounds/square foot (force)	0.00209
Ergs	Foot-pounds (force)	0.0737÷1000000
Ergs	Joules	0.10÷1000000
Ergs/second	Foot-pounds/second	0.0737÷1000000
Ergs/second	Watts	0.10÷1000000
Ergs/second-sq.cm.	Foot-pounds/second-.sq.ft.	68.47÷1000000
Ergs/second-sq.cm.	Watta/square metre	1÷1000
Fahrenheit	Centigrade	(F—32)×0.555
Fathoms	Feet	6
Feet	Centimetres	30.48
Feet	Metres	0.3048
Feet/minute	Metres/second	0.00508
Feet of water at 4°C	Inches of mercury at 0°C	0.8826
Feet of water at 4°C	Kilograms/sq.m.	304.8
Feet of water at 4°C	Newtons/sq.m.	2989
Feet of water at 4÷C	Pounds/sq.ft.	62.43
Feet of water at 4°C	Pounds/sq.inch	0.4335
Foot pounds	Kilogram-metres	0.1383
Gallons (Imperial)	Cubic metres	0.003785
Gallons (Imperial)	Gallons (US)	1.201
Gallons (Imperial)	Litres	4.545
Gauss	Lines/sq.inch	6.452
Gauss	Webers/sq.metre	0.0001
Gilberts	Ampere turns	0.7958
Grams	Dynes	980.7
Grams	Ounces (weight)	0.03527
Grams	Pounds (weight)	0.002205
Grams/sq.cm.	Pounds/square foot	2.0481
H.P.	Foot-pounds/minute	33000
H.P.	Kilowatts	0.746
H.P.	Kilograms-calories/minute	10.69
Inches	Centimetres	2.54
Inches	Metres	0.0254
Inches of water at 4°C	Kilograms/square metre	25.4
Inches of water at 4°C	Pounds/square foot	5.202
Joules	Foot-pounds	0.7376
Joules	Ergs	10×1000000
Kilogram-calories	Kilogram-metres	426.9
Kilograms	Grams	1000

TO CONVERT	INTO	MULTIPLY BY
Kilograms	Pounds (weight)	2.2046
Kilograms/sq.m.	Grams/sq.cm.	0.1
Kilograms/sq.m.	Pounds/sq.inch (weight)	0.001422
Kilograms/sq.m.	Pounds/sq.foot (weight)	0.2048
Kilogram/cubic metre	Pounds/cubic inch (weight)	0.036÷1000
Kilogram/cubic metre	Pounds/cubic foot (weight)	0.06243
Kilowatthours	Joules	3.6÷1000000
Kilowatthours	Kilogram-metres	367100
Litres	Cubic centimetres	1000
Litres	Cubic feet	0.03532
Litres	Cubic inches	61.03
Litres	Cubic metres	0.001
Litres	Gallons (Imperial)	0.2199
Litres	Pints	1.759
Metres	Centimetres	100
Metres	Inches	39.37
Metres	Feet	3.281
Metres	Yards	1.0936
Micro-bars (dynes/sq.cm.)	Newton/sq. metre	0.1
Micro-bars	Pounds/sq.foot	0.00209
Micro-bars	Pounds/sq.inch	0.0145÷1000
Miles (nautical)	Feet	6080
Miles (statute)	Feet	5280
Miles	Kilometres	1.6093
Miles/hour	Feet/minute	88
Miles/hour	Kilometres/hour	1.6093
Miles/hour	Metres/second	0.44704
Millimetres	Inches	0.03937
Mm water gauge 4°C	Inches water gauge 4°C	0.03937
Mm water gauge 4°C	Newtons/square metre	9.807
Mm water gauge 4°C	Pascals	9.807
Newtons	Dynes	100000
Newtons	Kilograms	0.1020
Newtons	Pounds	0.2248
Newtons/sq.m.	Dynes/sq.cm.	10
Newtons/sq.m.	Pounds/sq.foot (force)	0.020884
Newtons/sq.m.	Pounds/sq.inch	0.000145
Pounds (weight)	Grams	453.6
Pounds	Kilograms	0.4536
Pounds (force)	Newtons	4.448
Pounds of water	Cubic feet	0.01602
Pounds of water	Gallons	0.0997
Pounds/cubic feet. (weight)	Kilogram/cubic metre	16.02
Pounds/cubic inch	Pounds/cubic foot	1728
Pounds/sq.ft.	Grams/square cm.	0.4882
Pounds/sq.ft.	Kilograms/sq.metre	4.882
Pounds/sq.ft. (force)	Newtons/square metre	47.85
Pounds/sq.ft.	Pounds/sq.inch (force)	0.006944
Pounds/sq.inch (weight)	Kilograms/square metre	703.1
Pound/sq.inch (force)	Newtons/square metre	6894
Pounds/sq.inch (force)	Pounds/sq.ft. (force)	144
Poundals (force)	Dynes	13830
Poundals	Pounds (force)	0.031
Poundals	Newtons	0.1382
Rayls	Mks rayls	10
Square centimetres	Square inches	0.1550
Square feet	Square inches	144
Square feet	Square metres	0.0929
Square feet	Square yards	9
Square metres	Square feet	10.764
Square metres	Square inches	1550
Square metres	Square yards	1.196
Square miles	Acres	640
Square miles	Square kilometres	2.590
Tons (2240)	Tonnes (1000 Kg.)	1.016
Water gauge (inches)	Newtons/sq.m.	249
Water gauge (mm.)	Newtons/sq.m.	9.807
Watts	Ergs/second	10×1000000
Watts	Foot-pounds/minute	44.26
Watts	Horsepower	0.001341
Watts	Kilogram-calories/minute	0.01433
Watts/sq.m.	Watts/sq.cm.	0.1÷1000
Webers/sq.m.	Gauss	10×1000

FULL LOAD CURRENT OF THREE PHASE SETS

VOLTAGE		STANDARD THREE PHASE VOLTAGES @ 0.8p.f. AMPS							
	550/	440/ 254	415/ 240	400/ 230	380/ 220	346/ 200	220/ 127	208/ 120	190/ 110
kVA @ 0.8 P.F. 1	1.0	1.3	1.3	1.4	1.5	1.6	2.6	2.8	3.0
2	2.1	2.6	2.7	2.8	3.0	3.3	5.2	5.6	6.0
3	3.1	3.9	4.1	4.3	4.5	5.0	7.8	8.4	9.1
4	4.2	5.3	5.5	5.7	6.0	6.7	10.5	11.0	12.1
5	5.2	6.6	6.9	7.2	7.6	8.3	14.0	14.0	15.1
6	6.3	7.9	8.3	8.6	9.1	10.0	15.8	16.7	18.2
7	7.3	9.2	9.7	10.1	10.6	11.7	18.4	19.5	21.2
8	8.4	10.5	11.1	11.6	12.1	13.3	21	22.3	24.3
9	9.4	11.8	12.5	13	13.6	15.2	23.6	25	27.4
10	10.5	13	13.9	14	15	16.7	26	28	30
15	16	20	20.8	21	22.7	25.0	39	42	45
20	21	26	27.8	29	30	33.4	52	55	60
25	26	33	34.7	36	38	41.7	66	69	76
30	32	39	41.7	43	45	50.0	78	83	91
35	37	46	49	50	53	58.5	92	98	106
40	42	53	55	57	60	66.8	105	111	122
45	47	59	62	65	68	75.2	118	124	137
50	52	66	69	72	76	83.5	131	138	152
55	58	72	76	79	83	91.8	144	152	167
60	63	79	83	86	91	100	157	166	183
65	68	85	90	93	98	108	170	180	198
70	73	92	97	101	106	116	184	194	213
75	79	98	104	108	114	125	197	208	228
80	84	105	111	115	121	133.6	210	222	243
85	89	112	118	123	129	141	223	236	258
90	95	118	125	130	136	150	236	250	274
95	100	125	132	137	144	158	250	264	289
100	105	131	139	144	152	167.0	262	278	304
105	110	138	146	152	159	175	276	292	319
110	116	144	153	159	167	184	288	305	334
115	121	151	159	166	175	192	302	319	350
120	126	158	166	173	182	200	315	333	364
125	131	164	174	181	190	208	328	347	380
130	136	171	180	188	197	217	341	361	395
135	142	177	187	195	205	225	355	375	410
140	147	184	194	202	212	233	367	389	425
145	152	190	201	209	220	242	380	403	441
150	157	197	208	217	228	250	394	416	456
155	163	203	215	224	235	258	407	430	471
160	168	210	222	231	243	266	420	444	487
165	173	217	229	238	250	275	433	458	502
170	179	223	236	246	258	283	446	472	516
175	184	230	243	253	266	291	459	486	531
180	189	236	250	260	273	300	472	500	547
185	195	243	257	267	281	308	486	514	562
190	200	250	264	274	289	316	500	528	578
195	205	256	271	281	296	324	512	542	593
200	210	263	278	289	304	334	525	555	608
205	215	269	285	296	310	342	538	569	623
210	221	275	292	303	319	350	551	583	638
215	226	282	299	311	327	359	565	597	654
220	231	289	306	318	335	367	577	611	668
225	236	296	313	325	342	375	590	625	684
230	242	302	319	332	350	384	604	638	700
235	247	308	326	339	359	392	616	652	715
240	252	315	333	347	365	400	630	666	730
245	259	322	340	354	372	409	643	680	745
250	263	328	347	361	379	493	656	694	760
300	315	394	417	434	456	501	787	833	912
400	420	525	556	578	608	668	1050	1110	1215
500	525	656	695	722	760	835	1312	1389	1520
600	630	787	834	866	912	1002	1575	1665	1823
700	735	919	974	1010	1064	1169	1837	1943	2127
750	787	984	1043	1083	1140	1252	1968	2082	2279

FULL LOAD CURRENT OF SINGLE PHASE SETS

VOLTAGE		240	220	200	120	110	100
		STANDARD SINGLE PHASE VOLTAGE					
		AMPS					
kVA @ 0.8 P.F.	5	21	23	25	42	45	50
	10	42	45	50	84	91	100
	15	63	68	75	125	136	150
	20	83	91	100	166	182	200
	25	104	114	125	208	227	250
	30	125	136	150	250	272	300
	35	146	159	175	292	318	350
	40	167	182	200	334	364	400
	45	188	205	225	375	409	450
	50	208	227	250	417	454	500
	55	229	250	275	458	500	550
	60	250	273	300	500	546	600
	65	271	295	325	542	591	650
	70	292	318	350	584	636	700
	75	313	341	375	625	682	750
	80	333	364	400	666	727	800
	85	354	386	425	709	772	850
	90	375	409	450	750	818	900
	95	396	432	475	792	864	950
	100	417	455	500	834	909	1000
	105	438	477	525	875	954	1050
	110	458	500	550	916	1000	1100
	115	479	523	575	958	1046	1150
	120	500	546	600	1000	1091	1200
	130	542	591	650	1083	1182	1300
	135	563	614	675	1125	1227	1350
	140	583	636	700	1166	1272	1400
	145	604	659	725	1209	1318	1450
	150	625	682	750	1250	1364	1500
	155	646	704	775	1292	1409	1550
	160	667	727	800	1334	1454	1600
	165	688	750	825	1375	1500	1650
	170	708	773	850	1417	1545	1700
	175	729	795	875	1458	1590	1750
	180	750	818	900	1500	1636	1800
	185	771	841	925	1542	1682	1850
	190	791	864	950	1583	1728	1900
	195	812	886	975	1625	1772	1950
	200	833	909	1000	1666	1818	2000
	205	854	931	1025	1708	1863	2050
	210	875	954	1050	1750	1909	2100
	215	896	977	1075	1791	1954	2150
	220	917	1000	1100	1833	2000	2200
	225	937	1023	1125	1875	2046	2250
	230	958	1045	1150	1917	2091	2300
	235	979	1068	1175	1958	2136	2350
	240	1000	1091	1200	2000	2181	2400
	245	1021	1114	1225	2042	2227	2450
	250	1042	1136	1250	2082	2272	2500

Installation Questionnaire

Power Generation

Installation Questionnaire for Generating Sets

In order to accurately estimate the materials, technicalities and costing for any installation it is essential that all available data relating to the generator, location and room be itemised and documented before contacting the supplier. This service can alternatively be provided by your local Cummins Distributor.

Project ....
....
Customer (End User) ....
....
Address of Site ....
....
....
....
Consultant ....
....
Address ....
....
....
....
Telephone No. ....
Site Drawing No. ....
Architect ....
....

GENERATING SET DETAILS

Model .... kVA ....
p.f. .... kW ....
Voltage .... Phases ....
Frequency .... Engine ....
Alternator .... Control System ....
Number .... Size of Room ....
Position of Set(s) ....
indicate on site drawing if possible
Are Control Panels to be Integral ☐ or Free Standing ☐
Position of Free Standing Control Panel ....
....

Motor starting	YES ☐	NO ☐
UPS Load	YES ☐	NO ☐
Operate Lifts	YES ☐	NO ☐
Base Fuel Tank	YES ☐	NO ☐
Direct Feed from Bulk Tank	YES ☐	NO ☐

Position of Bulk Tank ....

SITE CONDITIONS

Brief description of site working conditions including time scale for installation: ....
....

Type of Crane ....
Distance to position of set from suitable crane position? ....
Is there hard standing for crane YES ☐ NO ☐
Type of Transport ....
Police Involvement YES ☐ NO ☐ Road Closure YES ☐ NO ☐

Access (obstructions, restrictions, etc.) ....
....

Is set to be positioned
IN BASEMENT ☐ GROUND LEVEL ☐
MID LEVEL ☐ ROOF TOP ☐
Is set to be dismantled YES ☐ NO ☐
ON PLINTHS ☐ R.S.J's ☐ FLOOR ☐

Special Access Requirements: ....
....
Radiator 40°C ☐ 50°C ☐
Is radiator to be Integral ☐ or REMOTE ☐ or OTHER ☐
Position of Remote radiator relative to both plant and control panel ....
....

EXHAUST

Type of flue to be used: Steel ☐ Twin wall stainless steel ☐
Overall length of exhaust Horiz ....Vert ....metres/ft.
Number of Bends ....
Type of Silencers: Residential ☐ Acoustic ☐ Other ☐
Type of Brackets: Roller ☐ Fixed ☐ Spring ☐
GLC type ☐ Mixed ☐
Pipework to be: Flanged ☐ Butt welded ☐
Residential Silencer to be:
floor mounted ☐ wall mounted ☐ ceiling mounted ☐
Acoustic Silencer to be:
floor mounted ☐ wall mounted ☐ ceiling mounted ☐
Exhaust weathering in: wall ☐ roof ☐
Termination in: tailpipe ☐ cowl ☐
Finish to pipework: red lead ☐ black epoxy paint ☐
Access for erecting pipework:
good ☐ bad ☐ scaffold required ☐
Welding supply available: YES ☐ NO ☐
Type of lagging: rockwool ☐ other ☐
Lagging thickness: 50mm ☐ 75mm ☐ other ☐
Type of cladding:
22 swg aluminium ☐ stainless steel ☐ other ☐
Length of pipe to be lagged and clad ....metres/ft.
Type of silencer to be lagged and clad: Residential ☐ Acoustic ☐

CABLE

Type of Load Cables:
PVCSWAPVC ☐ CSP/EPR ☐ Bus bar ☐ LSF ☐
Route length of control cables between plant and panel:
....metres/ft.
Type of control cables:
PVCSWAPVC ☐ PVC ☐ LSF ☐
Route length of control cables between plant and panel:
....metres/ft.
Size load cables ....
No per phase ....
Size of neutral cable i.e. 100% ☐ 200% ☐
or ....
Load and control cable run in:
Trunking ☐ On tray ☐ Clipped ☐
Load and control cables run overhead:
on wall ☐ on floor ☐ in trench ☐
Cable entry to panel: top ☐ bottom ☐ side ☐
Position of LTB: ....
Other control cables:
Service .... metres/ft
Cable Type .... metres/ft
Cable Route Length .... metres/ft

Installation Questionnaire

Power Generation

WATER

Pipe route length between remote radiator and engine:

..........metres/ft

Pipe route length between break tank and radiator:

.... metres/ft

Break Tank required: YES ☐ NO ☐

Pipework to be: screwed ☐ welded ☐

Pipework to be: galvanised ☐ steel ☐

FUEL

Type of bulk tank:

Cylindrical ☐ Rectangular ☐ Double skinned ☐ Bunded ☐

Capacity of bulk tank: ....

Standard Bosses ☐ Extra Bosses ☐

Position of Bulk Tank in relation to set: ....

(height above or below ground etc.)

Access for offloading: ....

Pipe route length between bulk tank and service tank:

flow .... return ....metres/ft

Local Atmosphere ☐ Remote Vent ☐ Route .... ☐

Pipework: below ground ☐ above ground ☐

Pipework to be jacketed: YES ☐ NO ☐

Pipe: Trace heated ☐ Denso ☐

Type of fillpoint required: Cabinet ☐ Valve, cap and chain ☐

Pipe route length between bulk tank and fill point: ....metres/ft

Fill alarm unit and tank float switch required:

YES ☐ NO ☐

Pipework: Thickness ....Single Skin ☐ Double Skin ☐

If double skin all pipe ☐ or specify ....

Pipework support/fixing ....

Type of bulk tank contents gauge:

Hydrostatic ☐ Electronic ☐ Mechanical ☐

Position of contents gauge: ....if not in fill point cabinet

Distance from bulk tank: .... metres/ft.

Service tank: free standing ☐ on set ☐

Overspill tank required: YES ☐ NO ☐

If tank free standing, pipe route length to engine:

.... metres/ft.

Auto fuel transfer system: YES ☐ NO ☐

Duplex YES ☐ NO ☐

Solenoid valve required: YES ☐ NO ☐

Position: ....

If pump positioned away from tank determine position: ....

....

Fire valve required: YES ☐ NO ☐

MERC: YES ☐ NO ☐

MKOB ☐ SQR ☐ BATT PACK ☐

Other alarms required: ....

Dump valve ☐

ATTENUATION

Level of noise to be obtained ....dB(A)

What distance.......... metres/ft.

Position of inlet splitter: low level ☐ high level ☐

Position of outlet splitter: low level ☐ high level ☐

Number of acoustic doors: ....

Type: single ☐ double ☐

Antivibration mounts required: YES ☐ NO ☐

Acoustic louvres: YES ☐ NO ☐

Noise survey required: YES ☐ NO ☐

Sound proof enclosure: YES ☐ NO ☐

Container ☐ Drop over ☐ Int fit out ☐

Walk round ☐ Close fit ☐ EEC style ☐

Paint finish ....RAL/BS4800 ....

DUCTING

Length of inlet duct: .... metres/ft.

No. of bends: ....

Length of outlet duct: .... metres/ft.

No. of bends: ....

Inlet duct: floor mounted ☐ wall mounted ☐ off ceiling ☐

Outlet duct: floor mounted ☐ wall mounted ☐ off ceiling ☐

Fire damper in inlet duct: YES ☐ NO ☐

Fire damper in outlet duct: YES ☐ NO ☐

LOUVRES

Inlet louvre ☐ Outlet louvre ☐

Type: fixed blade ☐ gravity ☐ motorised ☐

Position of louvre inlet: external ☐ internal ☐

Position of louvre outlet: external ☐ internal ☐

Colour finish to louvres: ....

If motorised spring open/motor closed ☐

motor open/spring closed ☐

Motor rating 24 V dc ☐ 240 ac ☐

Maintained supply by Others ☐ Battery Pack ☐

Genset Batteries ☐

COMMISSION

Distance from Genset/Conn .... metres/ft.

Load Bank ☐ Resistive ☐ Reactive ☐

Ground level ☐ Roof ☐ Other ☐

Weekend working ☐

Out of normal hours ☐

During normal hours ☐

Estimated duration of commissioning

2 days ☐ 3-5 days ☐ 1-2 weeks ☐ 3-4 weeks ☐ 5-6 weeks ☐

First fill of lub. oil: YES ☐ NO ☐ ....litres

First fill of fuel ☐ Quantity ☐ ....litres

Anti freeze ☐ YES ☐ NO ☐

Maintenance contract required:: YES ☐ NO ☐

Are civil works required: YES ☐ NO ☐

Set Length mm ....

Width mm ....

Height mm ....

Weight Kg ....

SYSTEM OPERATION

1 set AMF ☐ 2 or more AMF ☐ 2 set parallel ☐

2 or more parallel ☐ parallel with utility ☐

Brief description of operation details ....

....

DRAWINGS

Plant Room ☐ Builders/Civils ☐ Fuel Schematic ☐ Other ☐

COMPILED BY: ....

DATE: ....

WEIGHTS OF LIQUIDS			
Liquid	**lb/Imp Gallon**	**Kg per Litre**	**Specific Gravity**
Water	10.00	1.00	1.000
Lube Oil (SAE70)	9.00	0.92	0.916
Diesel Fuel	8.50	0.86	0.855
Kerosene	8.00	0.80	0.8000

Foundations – BEARING LOAD CAPABILITY			
Material	**Kg/Sq cm**	**PSI**	**KPA**
Rock, Hardpan	4.92	70	482
Hard clay, Gravel and Course Sand	3.93	56	386
Loose Medium Sand and Medium Clay	1.96	28	193
Loose Fine Sand	0.98	14	96.4
Soft Clay	0 to 0.98	0 to 14	0 to 96.4

Foundation Support Calculations

(also refer to Page B2 for Cummins Foundation Recommendations)

For generating sets **not** of Cummins manufacture and without built-in anti-vibration mountings and solidly mounted the following formula can be used but does result in excessively large concrete slabs.

To calculate the height of the foundation necessary to support the required weight (W) use the following:

$$h = \frac{W}{d \times l \times w}$$

where: h = height/depth of foundation in metres (feet).

l = Length of the foundation in metres (feet).

w = Width of the foundation in metres (feet).

d = Density of concrete – 2322kg/m3 (145 lbs/ft3).

W = Total net weight of Genset in kg (lbs) (see page B2 for Total Weight Calculations).

Energy Conversions

Unit Conversions

To convert from	Multiply by	To obtain
Heat		
kilocalorie	x 4.187	= kJ
British thermal unit	x 1.056	= kJ
BTU/cu. ft	x 37.294	kJ/cu. m
	x 0.037294	= MJ/cu.m
Power		
BTU/h	x 0.0002930	= kW
Kilocal/h	x 0.001163	= kW
metric horsepower	x 0.7335	= kW
(UK) horsepower (33,000 ft. lbf/min)	x 0.7457	= kW
ton refrigeration (12,000 BTU/h)	x 3.517	= kW

Pressure

mm of mercury (0 deg. C)	0.1333	= kPA
	x 0.001333	= bar
inch of mercury (0 deg. C)	x 3.386	= kPa
	x 0.0339	= bar
foot of water (4 deg. C)	x 2.989	= kPa
	x 0.0299	= bar
kg/sq. cm	x 98.066	= kPa
	x 0.9807	= bar
lb/sq. in (psi)	x 6.895	= kPa
	x 0.0689	= bar

Specific Fuel Consumption

kilocalorie per metric hp hr	x 0.005689	= MJ/kWh
BTU per bhp hr	x 0.001415	= MJ/kWh

Volume

cu.ft/min	x 0.0004719	= cu.m/s
cu.ft/hr	x 0.028	= sq.m/hr
cu.m/hr	x 35.313	= cu.ft/hr

General

To consider the possible layouts for a site, the following criteria must first be determined:-

The total area available and any restrictions within that area (i.e. buried or overhead services).

Position of exhaust and hot air outlets relative to surrounding buildings.

Any noise constraints. (i.e. the location of offices or residential property).

The access to the site, initially for delivery and installation purposes, but afterwards for the deliveries of fuel and servicing vehicles, etc.

The ground condition, is it level or sloping?

When installing the equipment within a plant room, consideration must be given to each of the following:-

A forced ventilation system is required for the equipment, which draws sufficient cooling and aspiration air into the room at the back of the alternator and discharges the air from in front of the engine. Dependent upon the layout of the building, it may be necessary to install additional ductwork to achieve the airflow required.

In order to reduce the heat gain within the plant room, all the elements of the off engine exhaust system will need to be fully lagged. Where practical, the silencer and as much of the pipework as possible should be outside the generator room.

The access into the building, initially for the delivery and installation of the equipment, and, afterwards for servicing and maintenance of the equipment.

The plant room should be of sufficient size to accommodate the following items of equipment:

- The engine/alternator assembly.
- The local fuel tank (if applicable).
- The generator control panel including the PCC (if free standing).
- The exhaust system (if internally erected).
- The air handling system including any sound attenuating equipment that may be required.

The relative height of the base for the bulk tanks should also be taken into consideration to determine the type of fuel transfer system that is to be utilised. The sizes for the bulk fuel storage tank(s) are dependent on the duration of the storage that is required and local authority limitations.

Where possible the equipment should be positioned in a manner such that "cross overs" of the ancillary services, (fuel, water and electrical power/controls) do not occur.

Due consideration should be given to the direction of the noise sensitive areas so that elements generating noise can be positioned to restrict any potential problem.(i.e. exhaust outlets).

Modular Installation

In terms of the external appearance the "drop-over" enclosure system is virtually identical to a containerised system. The principle difference between the two systems is that in the containerised arrangement the generator is mounted on the floor of the module, whereas in the "dropover" arrangement, the generator locates directly on the concrete plinth and the enclosure drops over onto the plinth.

To maintain the advantage of the reduction in site work, it is essential to give careful consideration to the positioning of the set to optimise the space and to minimise the lengths of any inter-connections.

Foundations

Note : Special foundations are unnecessary. A level and sufficiently strong concrete floor is adequate.

The responsibility for the design of the foundation (including seismic considerations) should be placed with a civil or structural engineer specialising in this type of work.

Major functions of a foundation are to:

- Support the total weight of the generating set.
- Isolate generator set vibration from surrounding structures.

To support the structural design, the civil engineer will need the following details:-

- the plant's operating temperatures (heat transfer from machines to mass could lead to undesirable tensile stresses).
- the overall dimensions of the proposed foundation mass.
- the mounting and fixing arrangements of the generator bedframe.

Off-loading and Positioning the Equipment

Prior to the commencement of the off-loading, using the specific site and equipment drawings, the positions for each of the principle items of equipment should be carefully marked out on the plinth/plant room floor.

The order in which various items of equipment are to be positioned should be determined to ensure that double lifting is avoided as far as possible.

The appropriate size and type of crane should be considered bearing in mind the site conditions and lifting radius. All the necessary lifting chains, spreader beams, strops etc., should be used to off-load and position the equipment.

Spreader beams should be used on all gensets to guard against damaging the panels and air filters.

Foundation Provisions

Slab Floor: For most Cummins Set applications, a massive foundation is not necessary for the generator set. The major issue will be installing the generator set so that its weight is properly supported and so that the unit can be easily serviced. A concrete pad or plinths should be poured on top of a concrete floor to raise the generator set to a height that makes service convenient and to make house-keeping around the unit easier.

- The pad should be constructed of reinforced concrete with a 28-day compressive strength of at least 17,200 kPa (2500 psi).
- The pad or plinths should be at least 150mm (6 inches) deep and extend at least 150mm (6 inches) beyond the skid on all sides.
- The mounting pad for the generator set should be level and flat to allow for proper mounting. Verify that the mounting pad is level lengthwide, widthwise, and diagonally.

Some generator sets may be provided with a design that features the engine/alternator solidly attached to the skid assembly. Generator sets that do not include integral isolation should be installed using vibration isolation equipment such as pad, spring, or air isolators.

NOTE: Bolting a generator set that does not include integral isolators directly to the floor or foundation will result in excessive noise and vibration; and possible damage to the generator set, the floor, and other equipment. Vibrations can also be transmitted through the building structure and damage the structure itself.

Foundations – Bolting Down

Should a suitable concrete base already exist or it is not convenient to use rag-bolts, then rawl-bolts or similar type of fixing bolt may be used. This obviates the necessity of preparing foundation bolt holes as already described. However, care should be taken that the correct size of masonry drill is used.

Vibration Isolation

Each generator built by Cummins Power Generation is a single module with the engine and alternator coupled together through a coupling chamber with **resilient anti-vibration mountings** fitted either between the genset and the skid or under the skid. Thus heavy concrete foundations normally used to absorb engine vibration are not necessary and all the generator requires is a level concrete floor that will take the distributed weight of the unit. The majority of engine vibration (approx 80%) is absorbed by this method and prevents transmissions through the floor to other areas.

Modularised System/Enclosed-Silenced Generators

In the design of the layout for this type of system the same constraints and guidance for the foundation should be observed, however, as the generator set and enclosure will be located directly onto the plinth, more care is required in its casting to ensure that it is flat and level with a "power float" type finish.

When the generator compartment is in the form of a dropover enclosure, it will be necessary to provide a weatherproofing sealing system in the form of angle section laid on an impervious strip seal. This will also act as a bund to retain fuel, water or oil spillage.

Total Weight

The total weight of the generator set, coolant, fuel, and foundation usually results in a soil bearing load (SBL) of less than 9800 kg/m^2 (2000 lbs/ft^2) 96 kPa (psi). Although this is within the load bearing capacity of most soils, always find out the allowable SBL by checking the local code and the soil analysis report for the building. Remember to include the weight of coolant, lubricant, and fuel (if applicable) when performing this calculation. Calculate the SBL by using the following formula:

$$\text{SBL (psi)} = \frac{W + (h \times w \times l \times d)}{l \times w \times 144}$$

Where:

h = Height of the foundation in meters (feet).
l = Length of the foundation in meters (feet).
w = Width of the foundation in meters (feet).
d = Density of Concrete – 2322 kg/M^3 (145 lbs/f^3).
W = Total wet weight of Genset in kg (lbs).
144 = Conversion ft^2 to in^2.

Plinths

The generator can be placed directly on a level, concrete floor, but where a permanent installation is intended, it is recommended that the unit is placed on two raised longitudinal plinths. This allows for easy access for maintenance and also allows a drip tray to be placed under the sump to meet fire regulation. Plinths should raise the plant 100 to 125mm above floor level, the actual height depending on the type of plant. The plinths are normally cast in concrete but RSJ's or timber can be used. If either of these two materials are used the bearers should be securely bolted down.

If in any doubt consult a Civil Engineer.

Bolting Down

Holding down bolts should also be used for anchoring the concrete plinths when necessary.

Caution: Ensure that the concrete is completely set and hardened before positioning the plant and tightening holding down bolts.

Levelling

A poor foundation may result in unnecessary vibration of the plant.

Connections

All piping and electrical connections should be finished with flexible end connections to prevent damage by movement of the plant during normal operation. Fuel and water lines, exhaust pipes and conduit can be affected by vibrations over long distances.

Power and Control Wiring Strain Relief

Power wiring and especially control wiring should be installed with the wiring supported on the mechanical structure of the generator set or control panel, and not the physical connection lugs or terminations. Strain relief provisions, along with the use of stranded control wiring rather than single core wiring help to prevent failure of the wiring or connections due to vibration.

300 kVA standard generator with base fuel tank in typical plant room.

Generator installations with acoustic treatment to achieve 85dBA at 1 metre

Note:- The layout drawings provided are intended as a guide and to form the basis of the installation design, but before the room design is finalised please ensure you have a "project specific" generator general arrangement drawing. Certain ambient temperatures or specific site requirements can affect the finalised generator build, layout configuration and room dimensions.

Room size allowance

The dimensions as indicated in the following tables allow for good maintenance/escape access around the generator. Ideally you should allow a minimum distance of 1 metre from any wall, tank or panel within the room.

Machine access

It is important to remember that the generator has to be moved into the constructed generator room, therefore the personnel access door has to be of a sufficient size to allow access alternatively the inlet/outlet attenuator aperture should be extended to the finished floor level, with the bottom uplift section built when the generator is in the room.

Inlet and outlet attenuators with weather louvres

The inlet and outlet attenuators should be installed within a wooden frame and are based on 100mm. airways with 200mm. acoustic modules. The attenuators should be fitted with weather louvres with a minimum 50% free area, good airflow profile and afford low restriction airflow access. The noise level of 85dB(A) at 1m will comply with minimum EEC Regulations. To achieve lower levels attenuator size can more than double in length.

The weather louvres should have bird/vermin mesh screens fitted on the inside, but these screens must not impede the free flow of cooling and aspiration air.

The outlet attenuator should be connected to the radiator ducting flange with a heat and oil resistant flexible connection. Refer to limitations on duct allowance in genset data sheet.

Canvas ducting between the radiator and duct work or attenuator should be a minimum of 300mm.

Exhaust systems

The exhaust systems shown on the layout drawings are supported from the ceiling. Should the building construction be such that the roof supports were unable to support the exhaust system, a floor standing steel exhaust stand will be needed. Exhaust pipes should terminate at least 2.3m above ground level to make it reasonably safe for anyone passing or accidentally touching.

Consideration must be given to the direction of exhaust from,

a) Avoidance of recirculation and

b) Direction of smoke plume in relation to other buildings, traffic, pedestrians.

It is recommended that stainless steel bellows be fitted to the engine exhaust manifold followed by rigid pipework to the silencer.

The dimension "E" as indicated on the layout diagrams is based upon using standard manufacturers silencers to achieve 85dBA at 1m, please ensure that the intended silencers to be used can be positioned as indicated as this dimension affects the builders works such as apertures to the walls for the exhaust outlet.

The exhaust run as indicated exits via the side wall through a wall sleeve, packed with a heat resistant medium and closed to the weather with wall plates.

Should the generator room, internally or externally, be constructed with plastic coated profiled steel sheet cladding, it is important to ensure that the wall sections at the exhaust outlet are isolated from the high exhaust pipe temperature and sealed by a specialist cladder. The same applies for any exhaust going through or near any timber or plastic guttering.

It is good installation practice for the exhaust system within the generator room to be insulated with a minimum of 50mm. of high density, high temperature mineral insulation covered by an aluminium overclad.

This reduces the possibility of operator burn injury and reduces the heat being radiated to the operating generator room.

Cable systems

The layout drawings assumes that the change-over switch-gear is external to the generator room and located in the power distribution room. Specific project requirements can affect this layout.

The power output cables from the generator output breaker to the distribution panel must be of a flexible construction:-

EPR/CSP	(6381TQ)
PCP	(H07RNF)

Should the cable route length from the generator to the distribution room be extensive the flexible cables can be terminated to a load terminal close box to the generator and then extended to the distribution room with armoured multi-core cables. (See typical load terminal box layout).

The flexible power cables should be laid in trefoil, placed on support trays/ladder rack in the trench with the recommended inter-spacing and segregated from the system control cables. The cables can also be laid in ducts or buried direct.

In all cases, the manufacturers instructions and rating tables should be consulted.

The cables should be correctly supported and rated for the installation/ambient conditions.

The flexible single core power cables entering any panel must pass through a non ferrous gland plate.

Change-over panels and Single Circuit Breakers.

Should the change-over panel be positioned within the generator room due note must be made of the floor/wall space that must be made available.

For change-over cubicles up to 700Amp. rating the wall mounting panel of maximum depth 350mm. can be mounted directly above the cable trench in the side access area without causing too many problems.

For change-over cubicles from 1000Amp. and above, a floor standing panel is used which needs additional space to be allocated. Refer to Page D23 for dimensions.

The room dimensions need to be increased in the area of the cable duct/change-over panel to allow space and personnel access around cubicles with the following dimensions. A minimum of 800mm. for rear access should be allowed unless front access only has been specified and agreed.

The cable trench in the area of the change-over cubicle needs to be increased in size to allow for the mains, load and generator cable access requirement.

Generator Sets.

All generators shown include 8 hour base fuel tanks. Free standing tanks can be provided but additional room space will be required.

Air inlet should be at the rear of the alternator to allow adequate circulation.

Avoid siting batteries close to alternator air intake.

Doors.

Doors should always open outwards. This not only makes for a better door seal when the set/s are running but allows for a quick exit/panic button or handle to get out. Make allowance for the generator to be moved into the room by using double doors at one end of the plant room.

Generator installations WITHOUT acoustic treatment.

Note: Handy rule of thumb for INTAKE louvres. Use 1.5 x radiator area.

All the previous notes regarding "generator installations with acoustic treatment" equally apply to installations without acoustic attenuators with the exception of paragraph 3 relating to the Inlet and Outlet louvres.

Inlet and outlet louvres.

The inlet and outlet weather louvres should be installed within a wooden frame with a minimum 50% free area, good airflow profile and low restriction airflow access.

The weather louvres should have bird/vermin mesh screens fitted on the inside, but must not impede the free flow of cooling and aspiration air.

The outlet weather louvre should be connected to the radiator ducting flange with a heat and oil resistant flexible connection.

When a radiator is mounted on the end of the plant main frame, position the set so that the radiator is as close to the outlet vent as possible, otherwise recirculation of hot air can take place. The recommended maximum distance away from the outlet vent is 150mm without air ducting.

Recommended Room Sizes

Terms of reference for room sizes.

Ambient temperature – 40°C.

Altitude – 150m.
(Depends on specific engine used in Gen Set.)

Ratings shown kVA – Prime @ 50 Hz.

Air flows 50 Hz – at 1500 rpm.

Air flows from – Radiator
– Aspiration
– Heat Radiation.

(Data from Technical Data Sheets Section G at Prime ratings.)

Attenuator dimensions – Based on 100mm airways
200mm acoustic modules.

Attenuator recommendations
– Should be fitted with weather louvres with a minimum 50% free area, good airflow profile and afford low restriction airflow access.
– Weather louvres should have bird/vermin mesh screens fitted on the inside, but must not impede the free flow of cooling and aspiration air.

Room clearance – min. 1m from any walls, fuel tank, or control panel within the room.

Air flows – Standby ratings at 50 Hz
– Provision has been made for running the generator in a standby mode for 1 hour in 24. If standby ratings are likely to be in excess of this period it is recommended that the factory be consulted. Radiator airflows remain the same for Prime or Standby ratings but aspiration air consumption will increase. This is in the region of approximately 10% increase over the aspiration engine air consumption at prime ratings.

Exhaust flows – Based on Technical Data Sheets shown in Section G.

Dimensions of sets – Based on Technical Data Sheets shown in Section G.

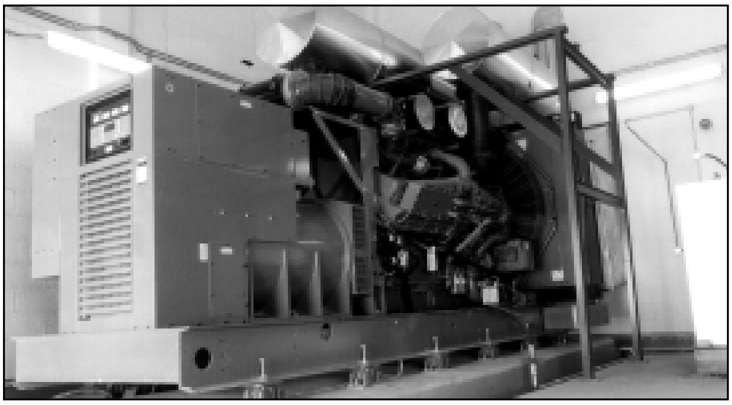
Trench sizes recommended – Based on kVA output of set.

50HZ CUMMINS ENGINE POWERED **32 kVA - 511 kVA** GENERATING SETS **WITHOUT** ACOUSTIC TREATMENT.

Prime Rating KVA	Type of ENGINE	TA Luft	Gen Set Model	Room dimensions Length A	width B	height C	Set back D	Set C/L position P	Exhaust Offset E	Height X	Outlet Louvre F	G	Uplift H	Inlet Louvre J	K	Cable trench position L	M	N
32.5	B3.3G1		26DGGC	3100	3000	2600	400	1500	159	2300	650	700	650	750	800	420	400	1165
50	B3.3G2		40DGHC	3100	3000	2600	400	1500	275	2300	750	800	650	900	900	420	400	1165
38	4B3.9G		30DGHC	3100	3000	2600	400	1500	141	2300	650	750	600	750	850	520	400	1325
52	4BT3.9G4	4g	42DGCG	3200	3000	2600	400	1500	194	2300	650	750	600	750	850	520	400	1325
64	4BT3.9G4	4g	51DGCH	3200	3000	2600	400	1500	194	2300	650	750	600	750	850	520	400	1325
70	4BTA3.9G1		56DGCC	3250	3000	2600	400	1500	194	2300	650	750	600	750	850	520	400	1410
96	6BT5.9G6		77DGDH	3500	3000	2600	400	1500	168	2300	700	860	540	800	800	520	400	1630
106	6BT5.9G6		85DGDJ	3500	3000	2600	400	1500	168	2300	700	860	540	800	800	520	400	1630
140	6BTA5.9G2		112DGDE	3600	3000	2700	400	1500	168	2300	800	950	540	1000	1000	520	400	1730
129	6CT8.3G2	4g	103DGEA	3850	3000	2700	400	1500	255	2300	850	1025	600	1000	1150	520	400	1910
153	6CTA8.3G	4g	122DGFA	3850	3000	2700	400	1500	255	2300	850	1025	600	1000	1150	520	400	1910
185	6CTA8.3G	4g	148DGFB	3850	3000	2700	400	1500	255	2300	850	1025	600	1000	1150	520	400	2070
204	6CTAA8.3G	4g	163DGFC	3950	3000	2700	400	1500	255	2300	850	1025	600	1000	1150	520	400	2070
230	6CTAA8.3G2		184DGFE	3950	3000	2700	400	1500	255	2300	850	1025	600	1000	1150	520	400	2070
233	LTA10G2		186DFAB	4850	3250	2800	500	1625	361	2300	1000	1075	520	1150	1250	625	400	2285
252	LTA10G3		202DFAC	4850	3250	2800	500	1625	361	2300	1000	1075	520	1150	1250	625	400	2285
313*	NT855G6		250DFBF	4850	3200	2700	500	1600	284	2300	1000	1300	700	1250	1400	625	400	2525
315	NT855G6		252DFBH	4850	3200	2700	500	1600	284	2300	1000	1300	700	1250	1400	625	400	2525
350	NTA855G4		280DFCC	4850	3200	2700	500	1600	284	2300	1000	1300	700	1250	1400	625	400	2525
425*	NTA855G6		340DFCE	4850	3200	2700	500	1600	284	2300	1000	1300	700	1250	1400	625	400	2630
431	KTA19G3		345DFEC	5275	3400	3000	500	1700	320	2500	1400	1450	700	1600	1675	775	400	2815
450	KTA19G3		360DFEL	5275	3400	3000	500	1700	320	2500	1400	1450	700	1600	1675	775	400	2815
511	KTA19G4		409DFED	5275	3400	3000	500	1700	320	2500	1400	1450	700	1600	1675	775	400	2815
455	QSX15-G8	4g	364DFEJ	5275	3400	3000	500	1700	442	2500	1400	1450	600	1600	1675	850	400	2815
500	QSX15-G8	4g	400DFEK	5275	3400	3000	500	1700	442	2500	1400	1450	600	1600	1675	850	400	2815

*Standby only.

Before finalising the generator room layout please ensure you read the guidance notes.

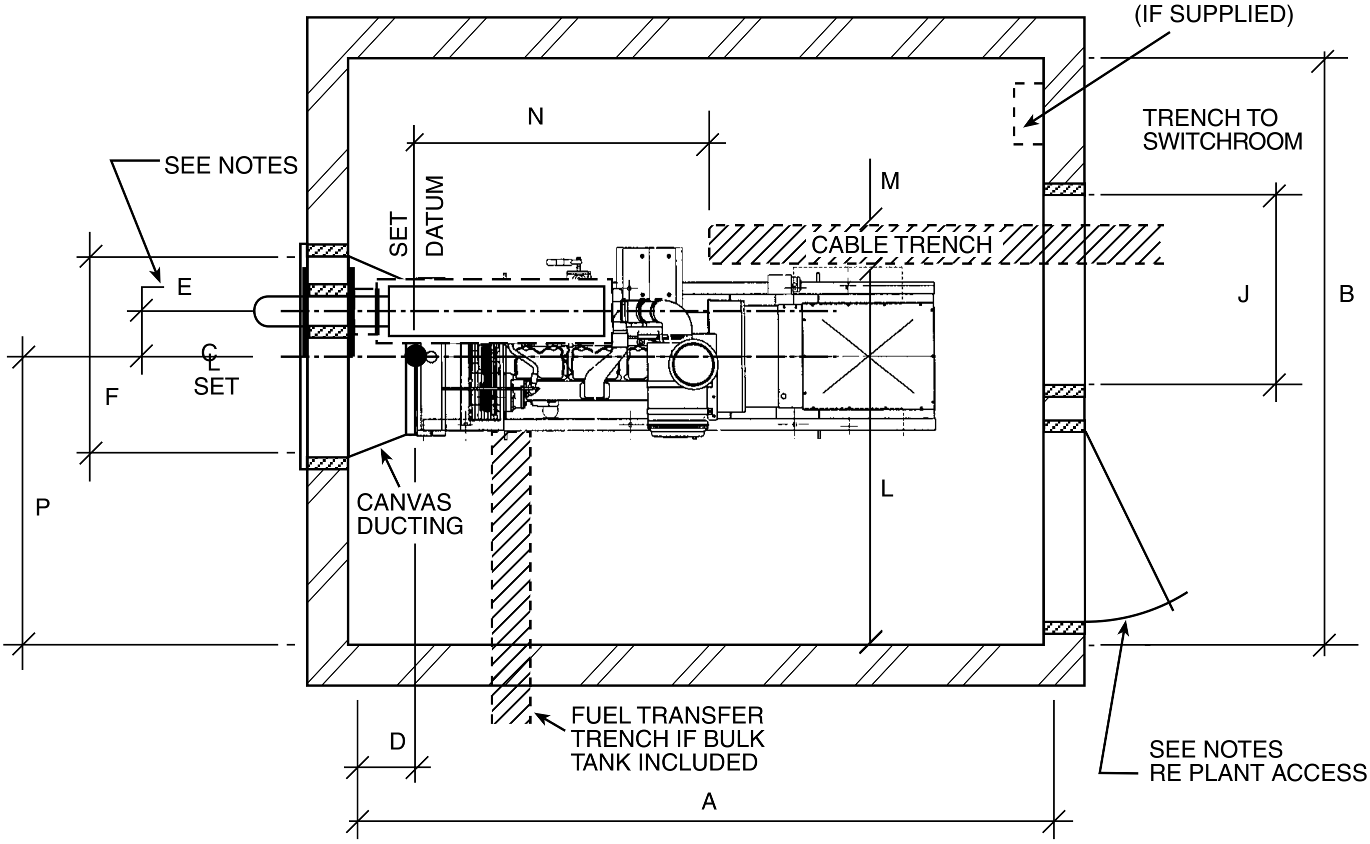


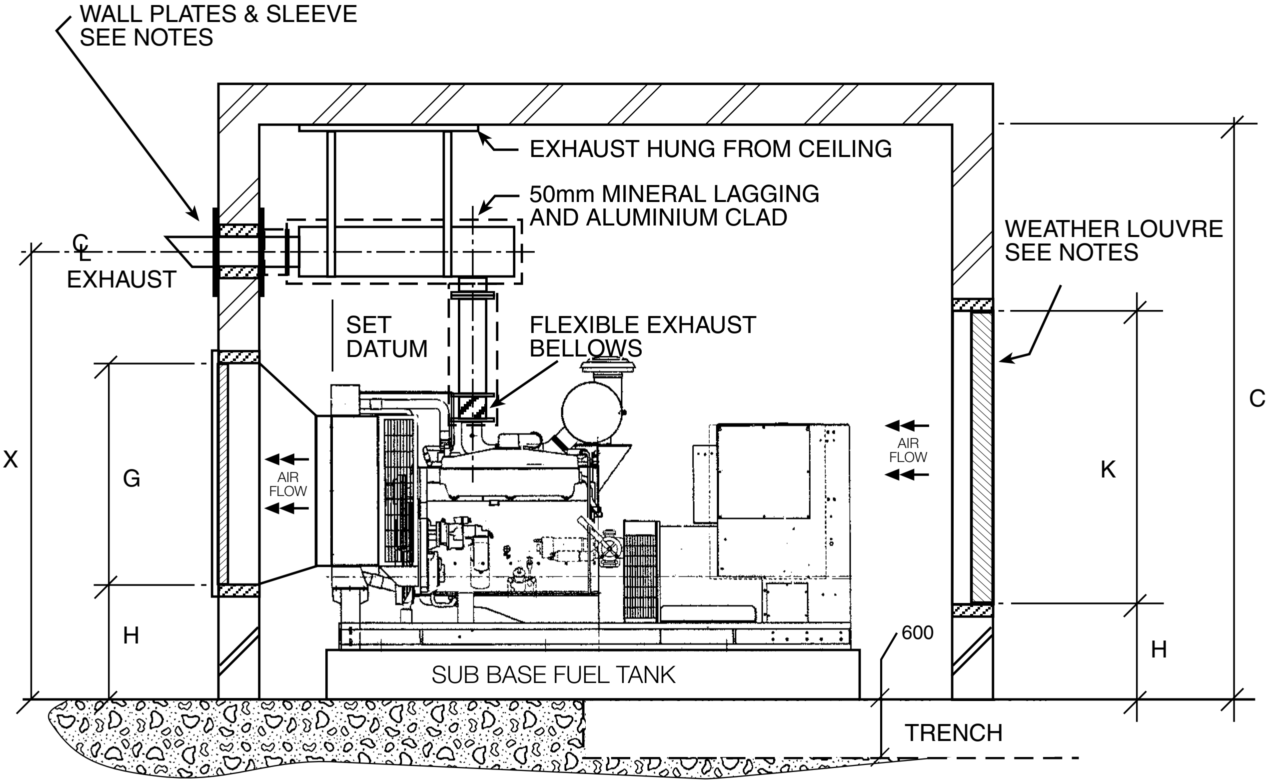
Note:– Unless otherwise stated all outputs are prime ratings at 50 Hz in ambient temperatures up to 40°C. Refer to Section G Technical Data Sheets for Standby Ratings.

Single 1256 kVA set installation with KTA50G3 engine illustrates silencer support and specially mounted anti-vibration springs utilised for roof top installations where noise transmissions through certain types of buildings may create a problem.

Cummins Generating Sets 32 kVA - 511 kVA

Generator 100m layout without Acoustic Treatment





Recommended Room Sizes

50HZ CUMMINS ENGINE POWERED **32 kVA - 511 kVA** GENERATING SETS **WITH** ACOUSTIC TREATMENT.

Prime Rating KVA	Type of ENGINE	TA Luft	Gen Set Model	Room dimensions			Set back D	Set position P	Exhaust		Attenuator Dimensions			Uplift H	Cable trench position		
				Length A	width B	height C			Offset E	Height X	F	Y	G		L	M	N
32	B3.3G1		26DGGC	4900	3000	2700	400	1500	159	2300	900	900	1000	400	420	400	1165
50	B3.3G2		40DGHC	4900	3000	2700	400	1500	275	2300	900	900	1000	400	420	400	1165
38	4B3.9G		30DGBC	4920	3000	2700	400	1500	168	2300	900	900	1000	400	520	400	1325
52	4BT3.9G4	4g	42DGCG	5000	3000	2700	400	1500	221	2300	900	900	1000	400	520	400	1325
64	4BT3.9G4	4g	51DGCH	5000	3000	2700	400	1500	221	2300	900	900	1000	400	520	400	1325
70	4BTA3.9G1		56DGCC	5000	3000	2700	400	1500	221	2300	900	900	1000	400	520	400	1410
96	6BT5.9G6		77DGDH	5600	3000	2700	400	1500	208	2300	900	1200	1000	400	520	400	1630
106	6BT5.9G6		85DGDJ	5600	3000	2700	400	1500	208	2300	900	1200	1000	400	520	400	1630
140	6BTA5.9G2		112DGDE	5700	3000	2700	400	1500	208	2300	900	1200	1200	400	520	400	1730
129	6CT8.3G2	4g	103DGEA	6300	3000	2800	400	1500	320	2300	900	1200	1200	400	520	400	1910
153	6CTA8.3G	4g	122DGFA	6300	3000	2800	400	1500	320	2300	900	1200	1200	400	520	400	1910
185	6CTA8.3G	4g	148DGFB	6300	3000	2800	400	1500	320	2300	900	1200	1200	400	520	400	2070
204	6CTAA8.3G1	4g	163DGFC	6450	3000	2800	400	1500	320	2300	1200	1200	1200	400	520	400	2070
230	6CTAA8.3G2		184DGFE	6450	3000	2800	400	1500	320	2300	1200	1200	1200	400	520	400	2070
233	LTA10G2		186DFAB	7100	3250	2900	500	1625	426	2400	1200	1200	1200	300	625	400	2285
252	LTA10G3		202DFAC	7100	3250	2900	500	1625	426	2400	1200	1200	1200	300	625	400	2285
313*	NT855G6		250DFBF	7840	3200	3000	500	1600	362	2500	1200	1200	1600	400	625	400	2525
315	NT855G6		252DFBH	7240	3200	3000	500	1600	362	2500	1200	1200	1600	400	625	400	2525
350	NTA855G4		280DFCC	7240	3200	3000	500	1600	362	2500	1200	1200	1600	400	625	400	2525
425*	NTA855G6		340DFCE	7360	3200	3200	500	1600	362	2700	1500	1200	1800	400	625	400	2630
431	KTA19G3		345DFEC	7775	3400	3250	500	1700	420	2750	1500	1200	1850	400	775	400	2815
450	KTA19G3		280DFEL	7775	3400	3250	500	1700	420	2750	1500	1200	1850	400	775	400	2815
511	KTA19G4		409DFED	7775	3400	3250	500	1700	420	2750	1500	1200	1850	400	775	400	2815
455	QSX15-G8		364DFEJ	7775	3400	3250	500	1700	542	2750	1500	1200	1850	400	850	400	2815
500	QSX15-G8	4g	400DFEK	7775	3400	3250	500	1700	542	2750	1500	1200	1850	400	850	400	2815

*Standby only.

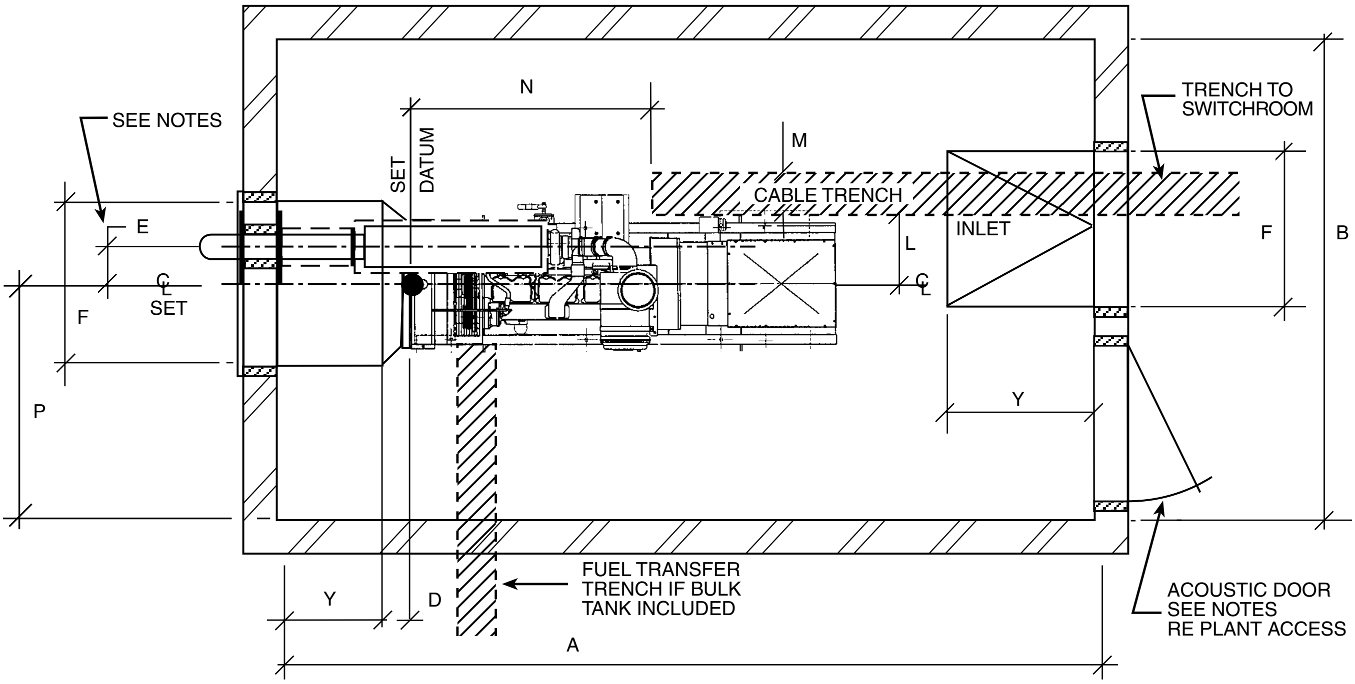
Before finalising the generator room layout please ensure you read the guidance notes.

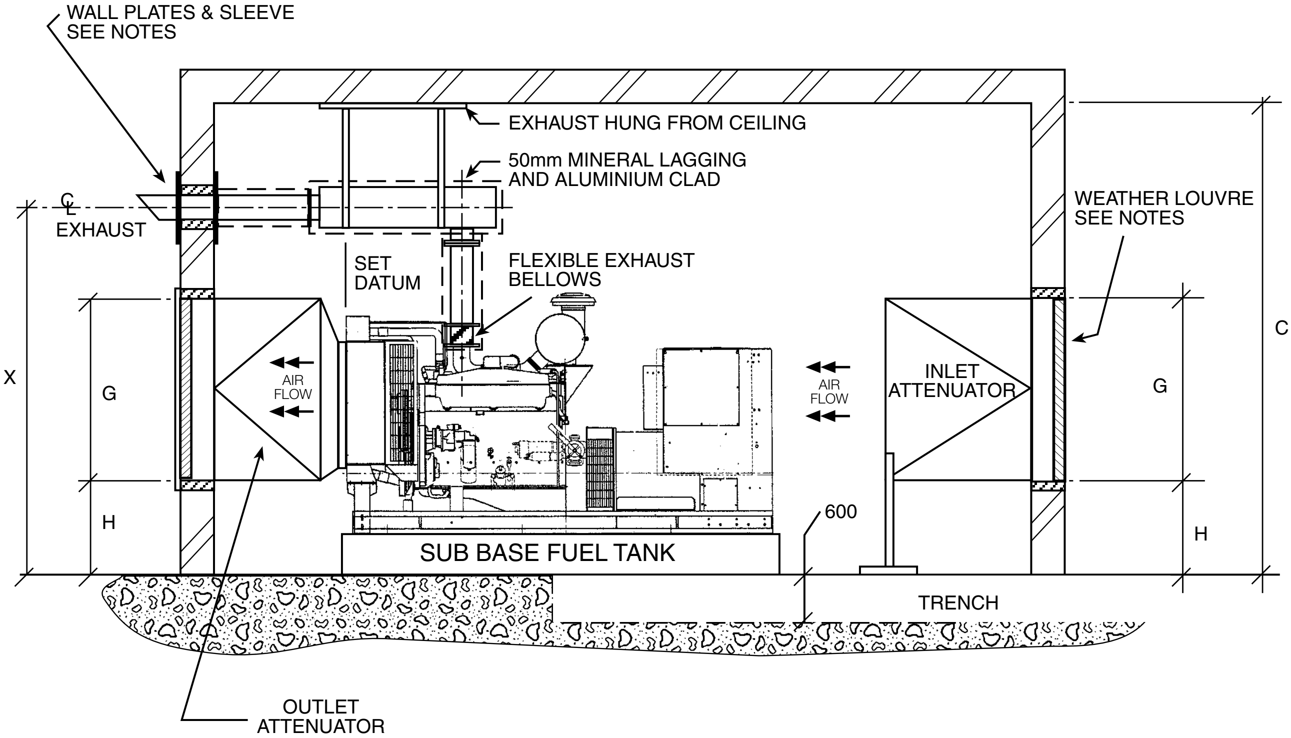
The attenuator dimensions indicated are based on 100mm airways and 200mm acoustic modules.

In free field conditions we would expect this treatment to achieve 85dBA at 1 metre.

Cummins Generating Sets 32 kVA - 511 kVA

Generator room layout with Acoustic Treatment to achieve 85dB(A) @ 1 metre



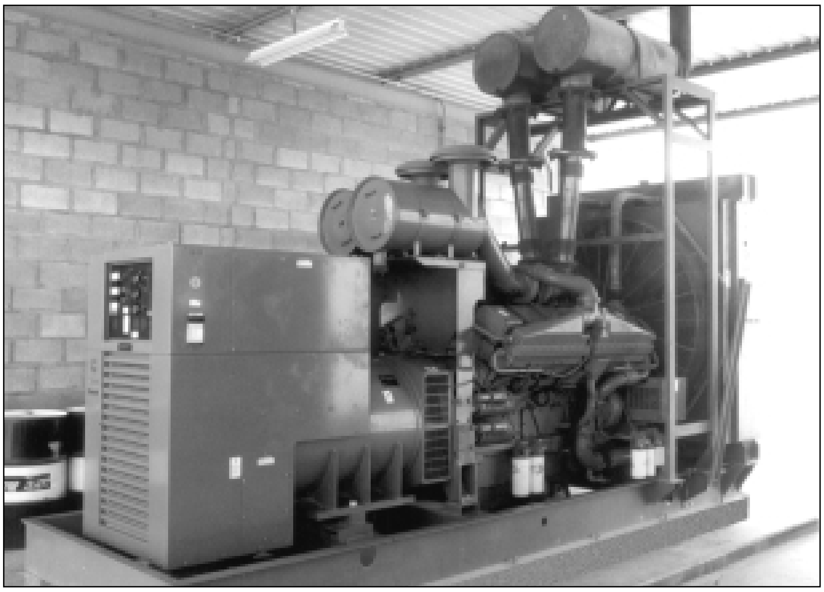


50HZ CUMMINS ENGINE POWERED **575 kVA - 2000 kVA** GENERATING SETS **WITHOUT** ACOUSTIC TREATMENT.

Prime Rating KVA	Type of ENGINE	TA Luft	Generator Model	Room dimensions Length A	width B	height C	Set back D	Set C/L position P	Exhaust Offset E	Height X	Outlet Louvre F	G	Uplift H	Inlet Louvre J	K	Cable trench position L	M	N
575	VTA28G5		460DFGA	5300	3450	3200	400	1725	300	2700	1500	1800	600	1800	2000	775	500	3150
640	VTA28G5		512DFGB	5300	3450	3200	400	1725	300	2700	1500	1800	600	1800	2000	775	500	3150
750	VTA28G6		600DFGD	5300	3450	3200	400	1725	300	2700	1500	1850	600	1850	2000	920	500	3150
725	QST30G1	4g	580DFHA	5960	3640	3400	500	1820	300	2950	1500	1850	600	1850	2000	920	500	3575
800	QST30G2	4g	640DFHB	5960	3640	3400	500	1820	300	2950	1500	1850	600	1850	2000	920	500	3575
939	QST30G3		751DFHC	5960	3640	3400	500	1820	300	2950	1500	1850	600	1850	2000	920	500	3575
1000	QST30G4		800DFHD	6050	3640	3500	500	1820	350	3000	1800	2150	600	2200	2350	920	600	3825
725	QST30G6	2g	580DFHE	5960	3640	3400	500	1820	300	2950	1500	1850	600	1850	2000	920	500	3575
800	QST30G7	2g	640DFHF	5960	3640	3400	500	1820	300	2950	1500	1850	600	1850	2000	920	500	3575
939	QST30G8	2g	751DFHG	5960	3640	3400	500	1820	300	2950	1500	1850	600	1850	2000	920	500	3575
936	KTA38G3		748DFJC	6050	3800	3400	500	1900	350	3000	1800	2150	600	2200	2350	920	500	3655
1019	KTA38G5		815DFJD	6050	3800	3500	500	1900	350	3000	1800	2150	600	2200	2350	920	600	3655
1256	KTA50G3		1005DFLC	6800	3800	3500	500	1900	350	3000	2100	2150	600	2200	2350	920	600	4375
1406	KTA50G8		1125DFLE	7500	4000	3500	500	2000	350	3000	2100	2150	600	2300	2600	920	600	5000
1500	KTA50GS8		1200DFLF	7500	3800	3500	500	1900	350	3000	2100	2150	600	2200	2350	920	600	5000
1256	KTA50G6	4g	1005DFLG	6800	3800	3500	500	1900	350	3000	2100	2150	600	2200	2350	920	600	4375
1256	KTA50G7	2g	1005DFLH	6800	3800	3500	500	1900	350	3000	2100	2150	600	2200	2350	920	600	4375
1875	QSK60G3		1500DQKC	7850	4500	4400	600	2250	693	3720	2600	2750	400	3000	3250	645	600	5000
2000	QSK60G4		1600DQKD	7850	4500	4400	600	2250	693	3720	2600	2750	400	3000	3250	645	600	5000
1875	QSK60G3	2g	1500DQKE	8200	4000	4400	800	2000	693	3720	2500	2500	400	2500	2500	645	600	3800
2000	QSK60GS3	2g	1600DQKF	8200	4000	4400	800	2000	693	3720	2500	2500	400	2500	2500	645	600	3800

1) Before finalising the generator room layout design please ensure you read the guidance notes.

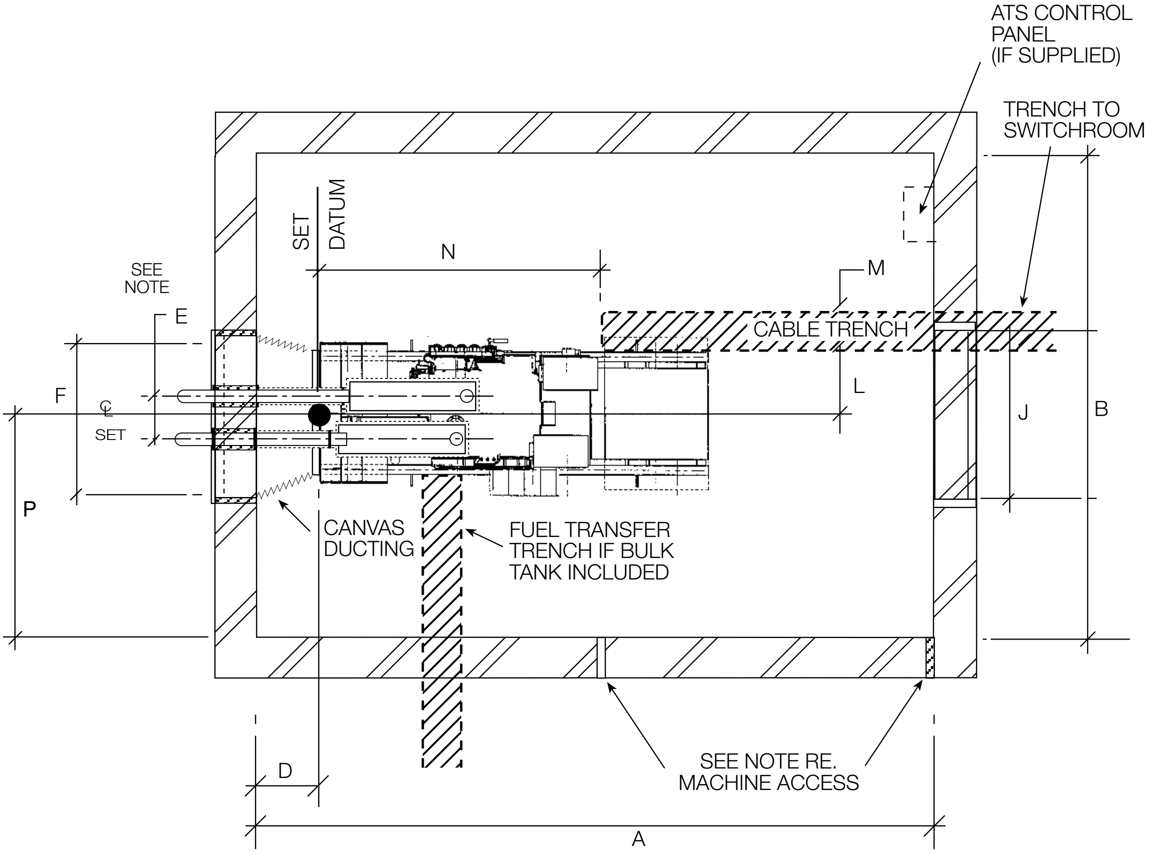
2) The QSK60 TA Luft engines are fitted with remote radiators, the room inlet louvre would be fitted with a pressurisation fan to cater for the engine heat radiated to the room, aspiration air and the alternator cooling air flow as detailed on the data sheet.

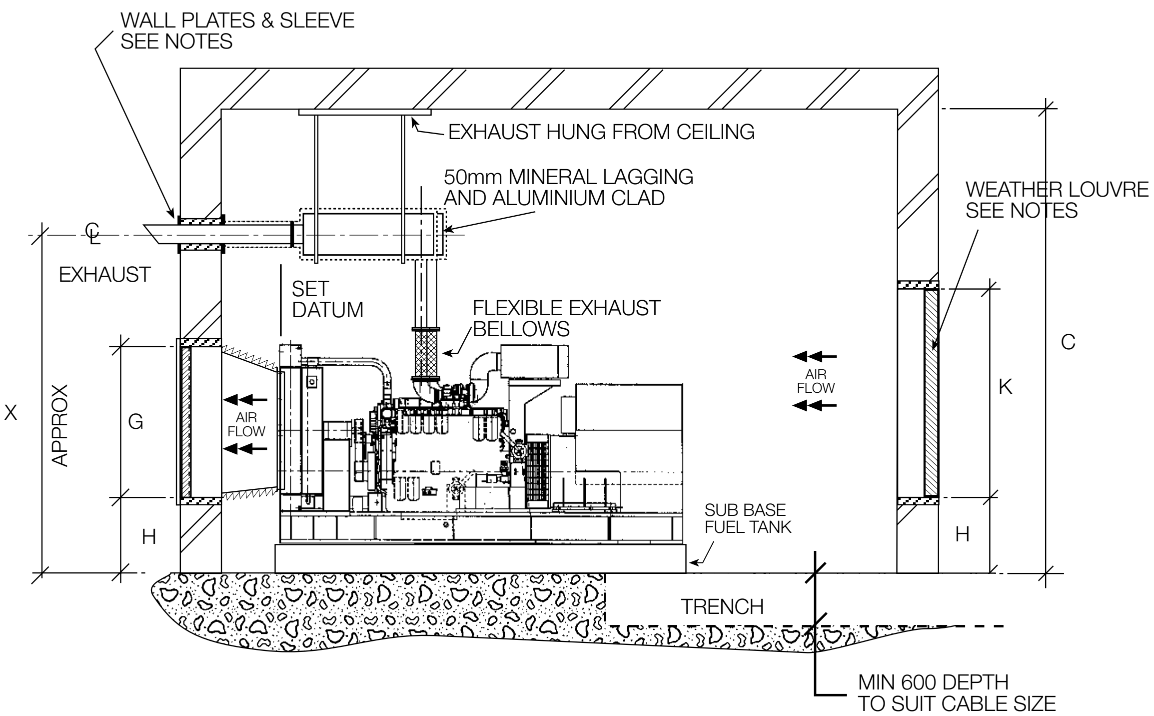


Model 512 DFGB (640 kVA) in a typical hot climate installation.

Cummins Generating Sets 575 - 2000 kVA

Generator room layout without Acoustic Treatment





Recommended Room Sizes

Cummins Power Generation

50HZ CUMMINS ENGINE POWERED **575 kVA - 2000 kVA** GENERATING SETS
WITH ACOUSTIC TREATMENT.

Prime Rating KVA	Type of ENGINE	TA Luft	Generator Model	Room dimensions Length A	width B	height C	Set back D	Set C/L position P	Exhaust Offset E	Height X	Attenuator Dimensions F	Y	G	Uplift H	Cable trench position L	M	N
575	VTA28G5		460DFGA	8400	3450	3450	400	1725	400	2950	1500	1500	2000	400	775	500	5150
640	VTA28G5		512DFGB	8400	3450	3450	400	1725	400	2950	1500	1500	2000	400	775	500	5150
750	VTA28G6		600DFGD	8400	3450	3450	400	1725	400	2950	1500	1500	2000	400	775	500	5150
725	QST30G1	4g	580DFHA	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
800	QST30G2	4g	640DFHB	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
939	QST30G3		751DFHC	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
1000	QST30G4		800DFHD	8450	3640	3800	500	1820	450	3150	2700	1200	2400	200	920	500	5100
725	QST30G6	2g	580DFHE	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
800	QST30G7	2g	640DFHF	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
939	QST30G8	2g	751DFHG	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
936	KTA38G3		748DFJC	9500	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	500	3655
1019	KTA38G5		815DFJD	9500	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	600	3655
1256	KTA50G3		1005DFLC	10360	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	600	4375
1405	KTA50G8		1125DFLE	11700	4000	4500	500	2000	500	3500	2450	2100	2600	200	920	600	5000
1500	KTA50GS8		1200DFLF	11700	3800	3800	500	1900	500	3100	2450	2100	2600	200	920	600	5000
1256	KTA50G6	4g	1005DFLG	10360	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	600	4375
1256	KTA50G7	2g	1005DFLH	10360	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	600	4375
1875	QSK60G3		1500DQKC	12650	4500	4500	600	2250	693	3800	2800	2400	2600	325	645	600	5000
2000	QSK60G4		1600DQKD	12650	4600	4500	600	2250	693	3920	3150	2400	3100	250	645	600	5000
1875	QSK60G3	2g	1500DQKE	11200	4000	4500	800	2000	693	3800	2700	1500	2500	325	645	600	3800
2000	QSK60GS3	2g	1600DQKF	11200	4000	4500	800	2000	693	3800	2700	1500	2600	325	645	600	3800

1) Before finalising the generator room layout design please ensure you read the guidance notes.

2) The attenuator dimensions indicated are based on 100mm. Airways and 200mm. Acoustic modules.

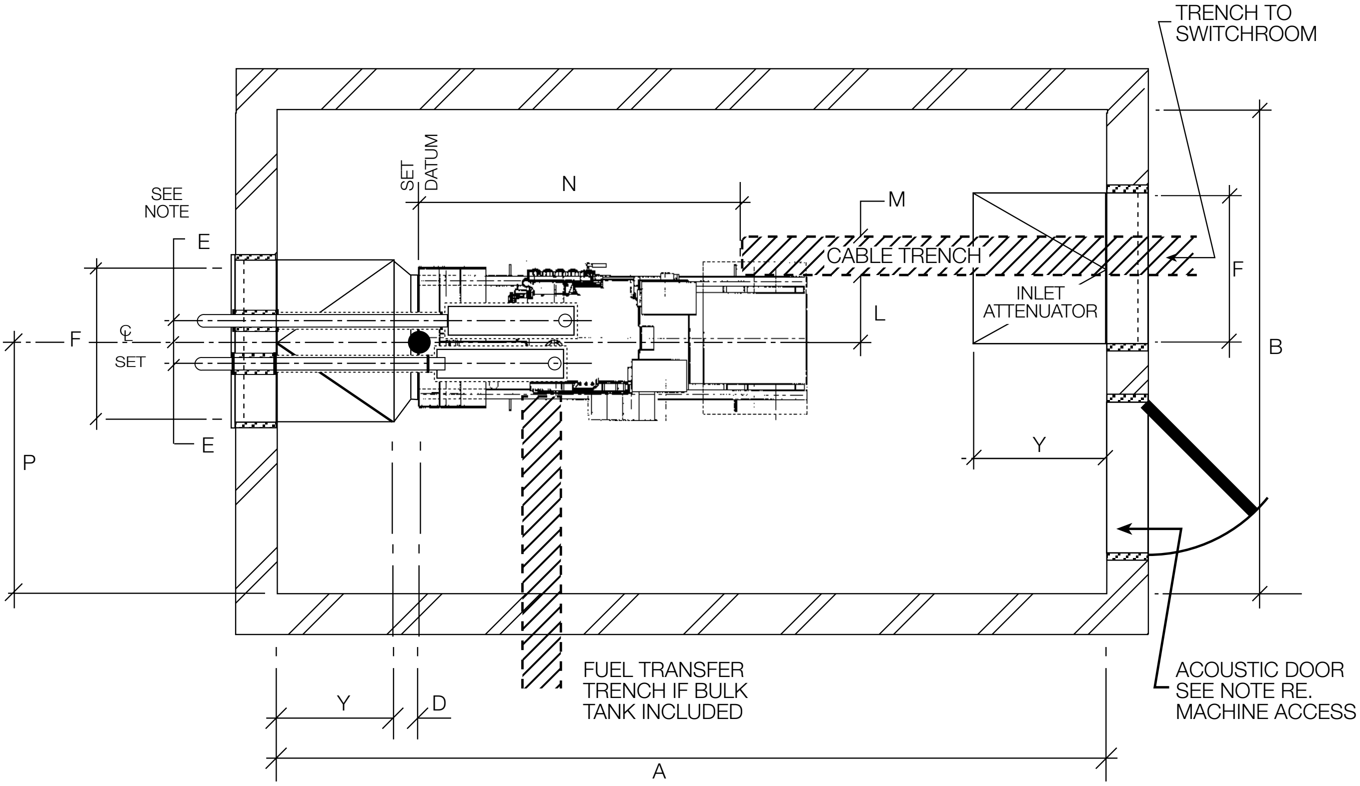
3) In free field conditions we would expect this treatment to achieve 85dBA at 1 metre.

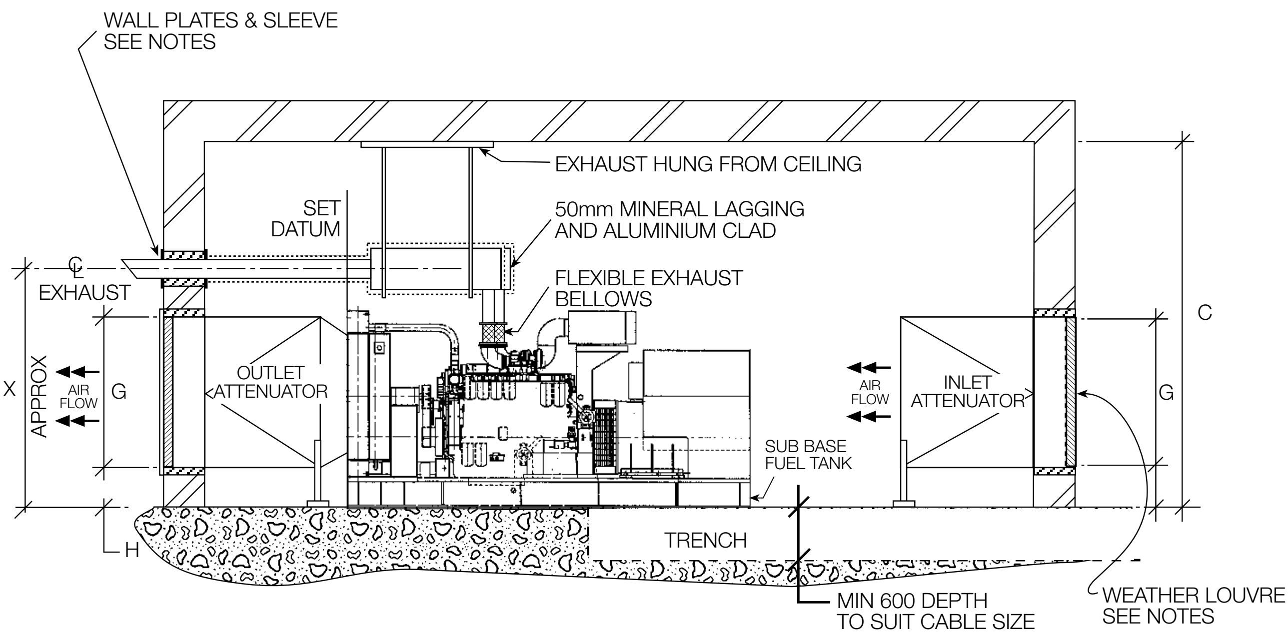
4) The QSK60 TA Luft engines are fitted with remote radiators, the room inlet attenuator would be fitted with a room pressurisation fan to cater for engine heat radiated to room, aspiration air and the alternator cooling air flow as detailed on the data sheet.

Good example of purpose made building to house two 1000 kVA generators with sound attenuators extending to the outside.

Cummins Generator Sets 575 - 2000 kVA

Generator room layout **with Acoustic Treatment** to Achieve 85dBA @ 1 metre





Recommended Room Sizes

ROOM WITH TWO GENERATORS INSTALLED.

50HZ CUMMINS ENGINE POWERED 233 kVA - 511 kVA GENERATING SETS

WITHOUT ACOUSTIC TREATMENT.

Prime Rating KVA	Type of ENGINE	TA Luft	Gen Set Model	Room dimensions			Positions			Exhaust		Outlet Louvre		Uplift	Inlet Louvre		Cable trench position		
				Length A	width B	height C	apart Z	back D	set C/L P	Offset E	Height X	F	G	H	J	K	L	M	N
233	LTA10G2		186DFAB	4850	6300	2800	2250	500	2425	361	2300	1000	1075	520	1150	1250	625	400	2285
252	LTA10G3		202DFAC	4850	6300	2800	2250	500	2425	361	2300	1000	1075	520	1150	1250	625	400	2285
313*	NT855G6		250DFBF	4850	6200	2700	2200	500	2425	284	2300	1000	1300	700	1250	1400	625	400	2525
315	NT855G6		252DFBH	4850	6200	2700	2200	500	2425	284	2300	1000	1300	700	1250	1400	625	400	2525
350	NTA855G4		280DFCC	4850	6200	2700	2200	500	2425	284	2300	1000	1300	700	1250	1400	625	400	2525
425*	NTA855G6		340DFCE	4850	6200	2700	2200	500	2425	284	2300	1000	1300	700	1250	1400	625	400	2630
431	KTA19G3		345DFEC	5275	6600	3000	2400	400	2500	320	2500	1400	1450	700	1600	1675	775	400	2815
450	KTA19G3		360DFEL	5275	6600	3000	2400	400	2500	320	2500	1400	1450	700	1600	1675	775	400	2815
511	KTA19G4		409DFED	5275	6600	3000	2400	400	2500	320	2500	1400	1450	700	1600	1675	775	400	2815
455	QSX15-G8	4g	364DFEJ	5275	6600	3000	2400	400	2500	442	2500	1400	1450	600	1600	1675	850	400	2815
500	QSX15-G8	4g	400DFEK	5275	6600	3000	2400	400	2500	442	2500	1400	1450	600	1600	1675	850	400	2815

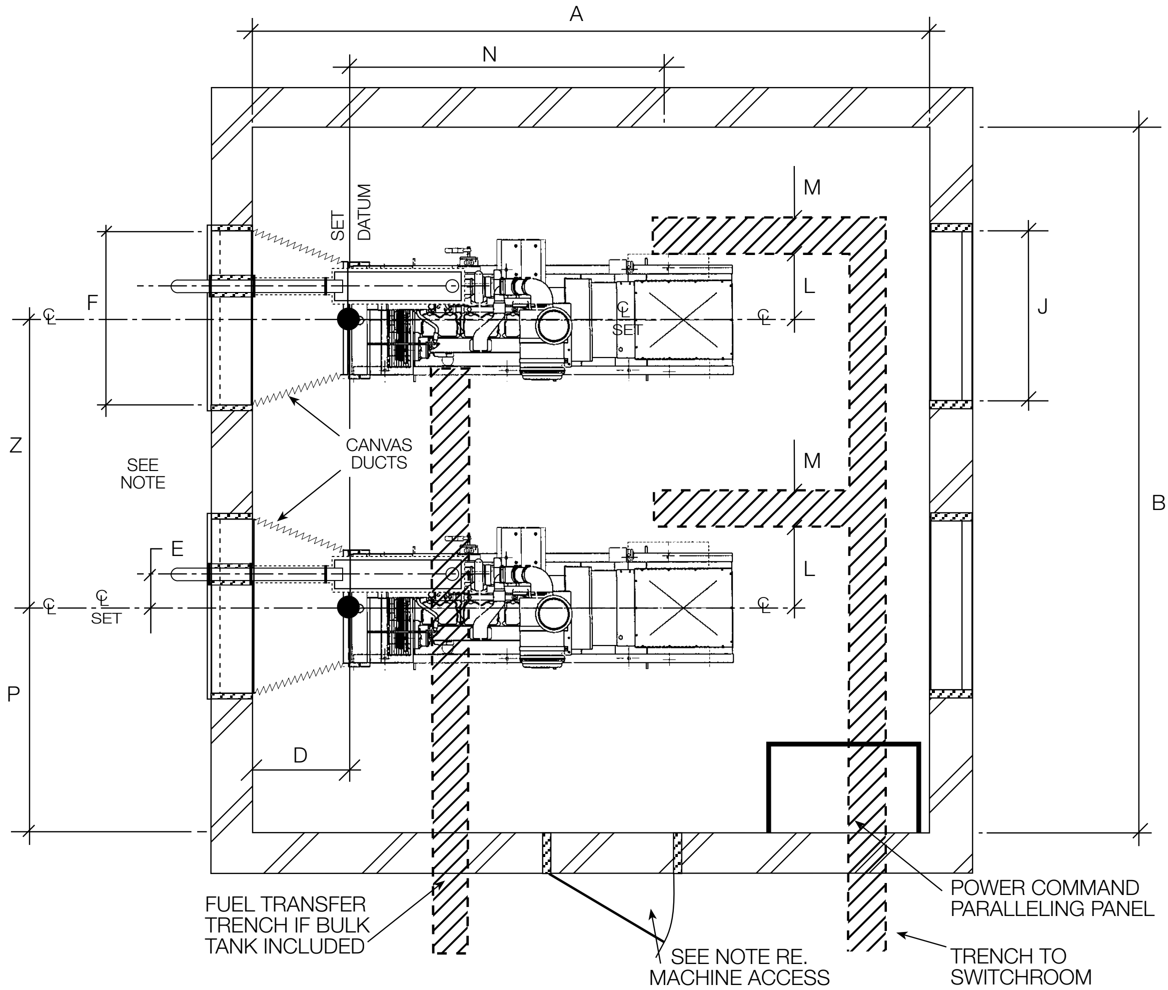
*Standby only.

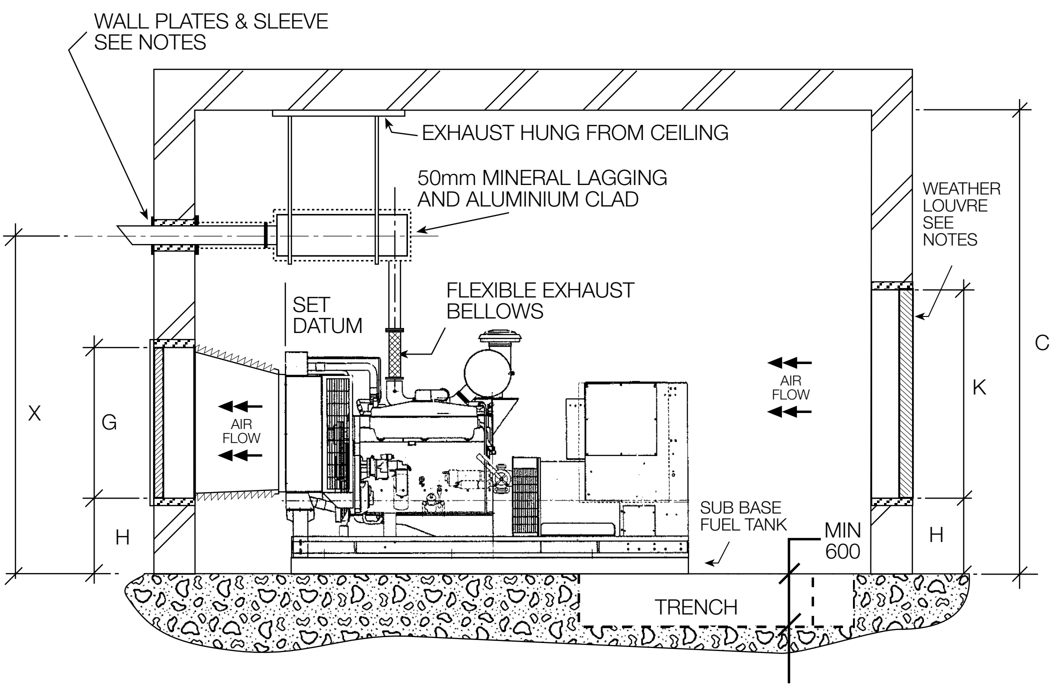
Before finalising the generator room layout please ensure you read the guidance notes.

Twin 800 DFHD sets (1000 kVA) with QST30 G4 engines, PCC control and DMC autosync cubicle in a typical installation.

Cummins Generating Sets 233 - 511 kVA

2 Set installation without Acoustic Treatment





ROOM WITH **TWO** GENERATORS INSTALLED.

50HZ CUMMINS ENGINE POWERED **233 kVA - 511 kVA** GENERATING SETS

WITH ACOUSTIC TREATMENT.

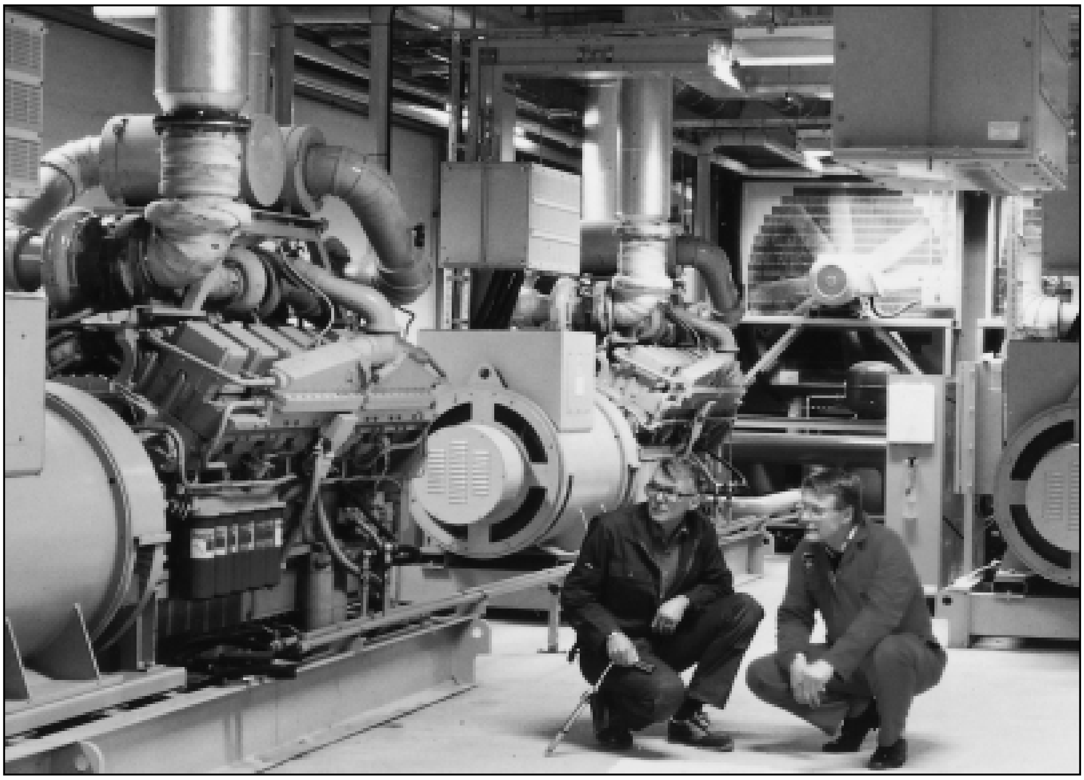
Prime Rating KVA	Type of ENGINE	TA Luft	Gen Set Model	Room dimensions Length A	width B	height C	Positions apart Z	back D	set C/L P	Exhaust Offset E	Height X	Attenuator Dimensions F	Y	G	Uplift H	Cable trench position L	M	N
233	LTA10G2		186DFAB	7700	6300	2900	2250	500	2425	426	2400	1200	1500	1200	300	625	400	2285
252	LTA10G3		202DFAC	7700	6300	2900	2250	500	2425	426	2400	1200	1500	1200	300	625	400	2285
313*	NT855G6		250DFBF	7840	6200	3000	2200	500	2425	362	2500	1200	1500	1600	400	625	400	2525
315	NT855G6		252DFBH	7840	6200	3000	2200	500	2425	362	2500	1200	1500	1600	400	625	400	2525
350	NTA855G4		280DFCC	7840	6200	3000	2200	500	2425	362	2500	1200	1500	1600	400	625	400	2525
425*	NTA855G6		340DFCE	7960	6200	3200	2200	500	2425	362	2700	1500	1500	1800	400	625	400	2630
431	KTA19G3		345DFEC	8375	6600	3250	2400	400	2500	420	2750	1500	1500	1850	400	775	400	2815
450	KTA19G3		360DFEL	8375	6600	3250	2400	400	2500	420	2750	1500	1500	1850	400	775	400	2815
511	KTA19G4		409DFED	8375	6600	3250	2400	400	2500	420	2750	1500	1500	1850	400	775	400	2815
455	QSX15-G8	4g	364DFEJ	8375	6600	3250	2400	400	2500	542	2750	1500	1500	1850	400	850	400	2815
500	QSX15-G8	4g	400DFEK	8375	6600	3250	2400	400	2500	542	2750	1500	1500	1850	400	850	400	2815

*Standby only.

Before finalising the generator room layout please ensure you read the guidance notes.

The attenuator dimensions indicated are based on 100mm. airways and 200mm acoustic modules.

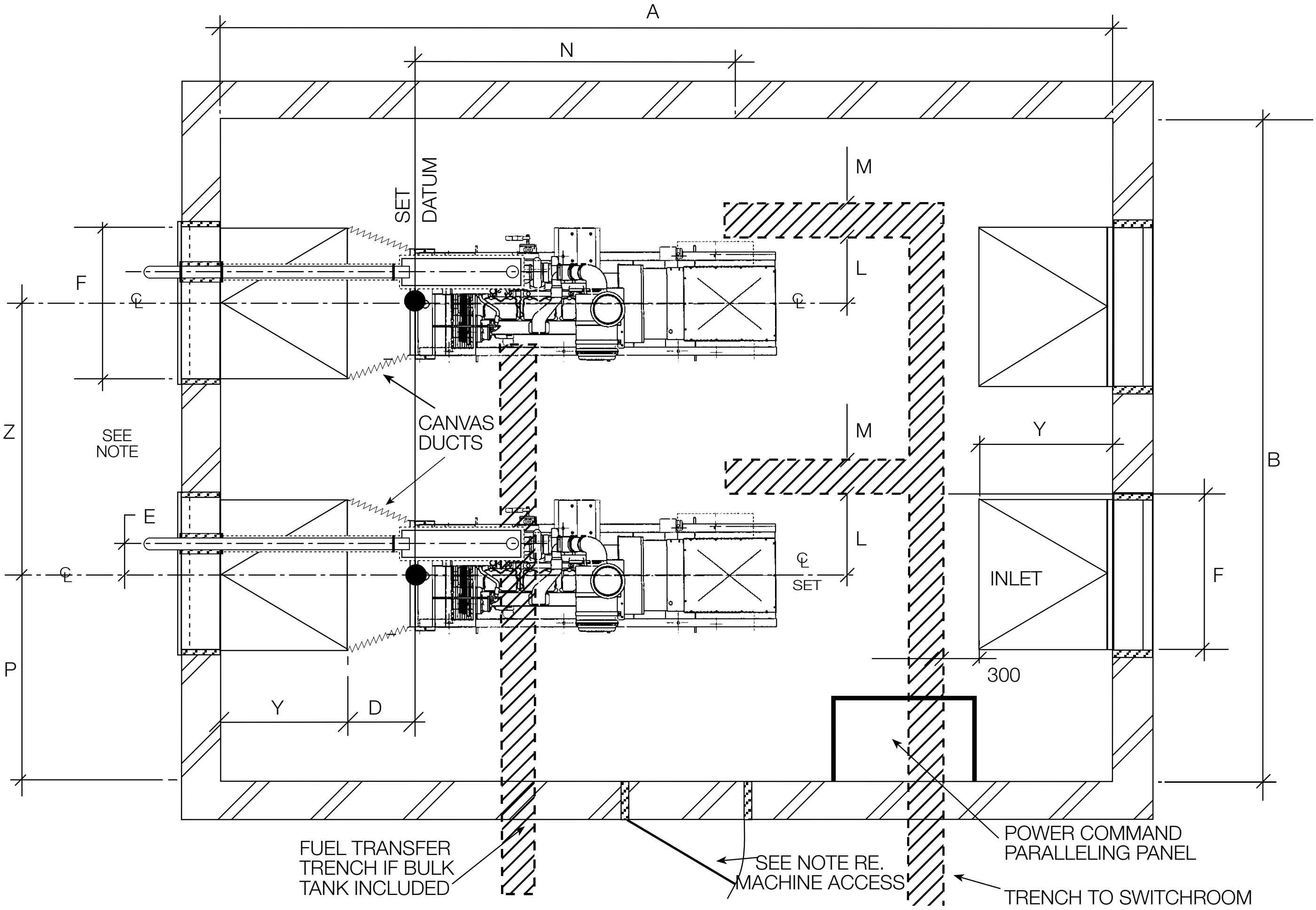
In free field conditions we would expect this treatment to achieve 85dBA at 1 metre.

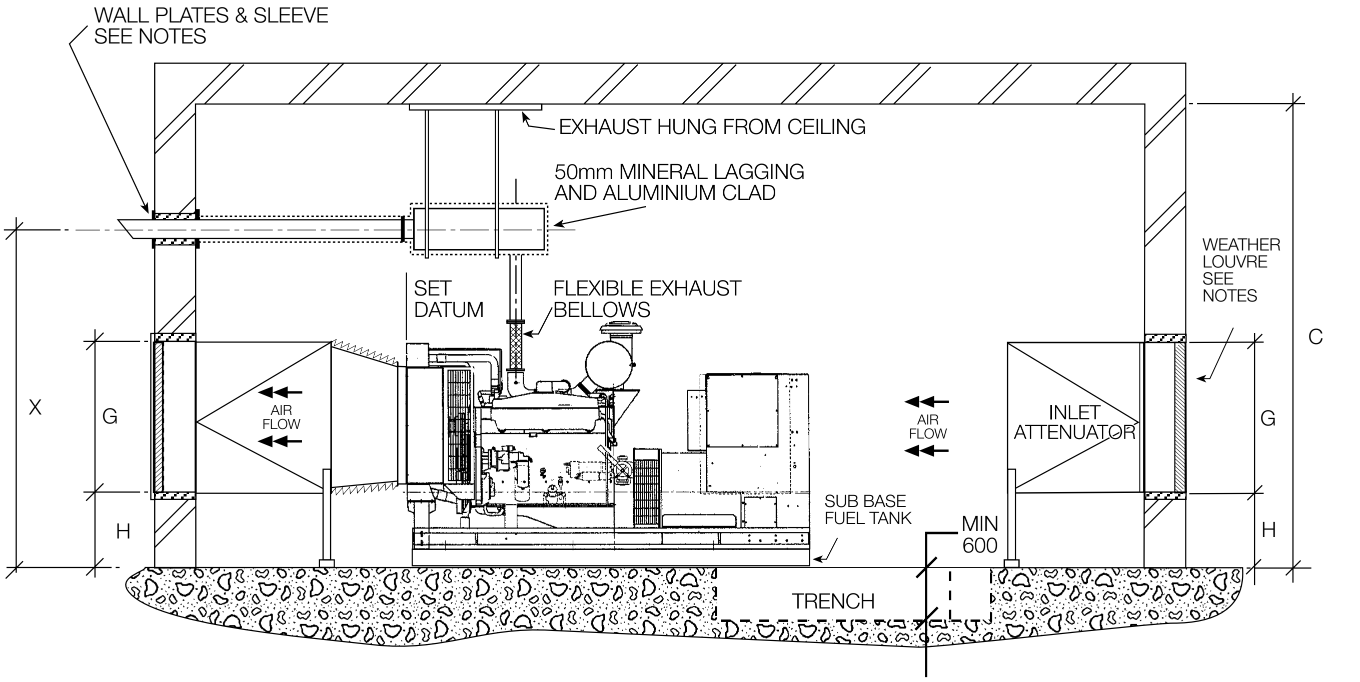


Three 1256 kVA standby sets with Cummins KTA50G engines provide backup to 150 computer centres in Norway.

Cummins Generating Sets 233 - 511 kVA

Room layout for 2 Set installation with Acoustic Treatment to Achieve 85dBA @ 1 metre





ROOM WITH **TWO** GENERATORS INSTALLED.

50HZ CUMMINS ENGINE POWERED **575 kVA - 2000 kVA** GENERATING SETS

WITHOUT ACOUSTIC TREATMENT.

Prime Rating KVA	Type of ENGINE	TA Luft	Gen Set Model	Room dimensions Length A	Room dimensions width B	Room dimensions height C	Positions apart Z	Positions back D	Positions set C/L P	Exhaust Offset E	Exhaust Height X	Outlet Louvre F	Outlet Louvre G	Uplift H	Inlet Louvre J	Inlet Louvre K	Cable trench position L	Cable trench position M	Cable trench position N	
575	VTA28G5		460DFGA	5300	6700	3200	2450	400	2575	300	2700	1500	1800	600	1800	2000	775	500	3500	
640	VTA28G5		512DFGB	5300	6700	3200	2450	400	2575	300	2700	1500	1800	600	1800	2000	775	500	3500	
750	VTA28G6		600DFGD	5300	6700	3200	2450	400	2575	300	2700	1500	1850	600	1850	2000	775	500	3500	
725	QST30G1	4g	580DFHA	5960	7080	3400	2640	500	2620	300	2950	1500	1850	600	1850	2000	920	500	3900	
800	QST30G2	4g	640DFHB	5960	7080	3400	2640	500	2620	300	2950	1500	1850	600	1850	2000	920	500	3900	
939	QST30G3		751DFHC	5960	7080	3400	2640	500	2620	300	2950	1500	1850	600	1850	2000	920	500	3900	
1000	QST30G4		800DFHD	6050	7080	3500	2640	500	2620	350	3000	1800	2150	600	2200	2350	920	600	4200	
725	QST30G6	2g	580DFHE	5960	7080	3400	2640	500	2620	300	2950	1500	1850	600	1850	2000	920	500	3900	
800	QST30G7	2g	640DFHF	5960	7080	3400	2640	500	2620	300	2950	1500	1850	600	1850	2000	920	500	3900	
939	QST30G8	2g	751DFHG	5960	7080	3400	2640	500	2620	300	2950	1500	1850	600	1850	2000	920	500	3900	
936	KTA38G3		748DFJC	6050	7400	3500	2800	500	2700	350	3000	1800	2150	600	2200	2350	920	500	3655	
1019	KTA38G5		815DFJD	6200	7400	3500	2800	500	2700	350	3000	1800	2150	600	2200	2350	920	600	3655	
1256	KTA50G3		1005DFLC	6800	7400	3500	2800	500	2700	350	3000	1800	2150	600	2200	2350	920	600	5000	
1405	KTA50G8		1125DFLE	7500	7800	3500	3000	600	2800	350	3000	2100	2150	600	2300	2600	920	600	5700	
1500	KTA50GS8		1200DFLF	7500	7800	3500	3000	600	2800	350	3000	2100	2150	600	2300	2600	920	600	5700	
1256	KTA50G6	4g	1005DFLG	6800	7400	3500	2800	500	2700	350	3000	1800	2150	600	2200	2350	920	600	5000	
1256	KTA50G7	2g	1005DFLH	6800	7400	3500	2800	500	2700	350	3000	1800	2150	600	2200	2350	920	600	5000	
1875	QSK60G3		1500DQKC	7850	8800	4400	3500	600	3050	693	3720	2600	2750	325	3000	3250	645	600	4805	
2000	QSK60G4		1600DQKD	7850	8800	4400	3500	600	3050	693	3720	3150	2750	325	3500	3300	645	600	5000	
1875	QSK60G3	2g	1500DQKE	8200	7000	4400	3000	800	2000	693	3720	2500	2500	325	2500	2500	645	600	3800	Note 2
2000	QSK60GS3	2g	1600DQKF	8200	7000	4400	3000	800	2000	693	3720	2500	2500	325	2500	2500	645	600	3800	Note 2

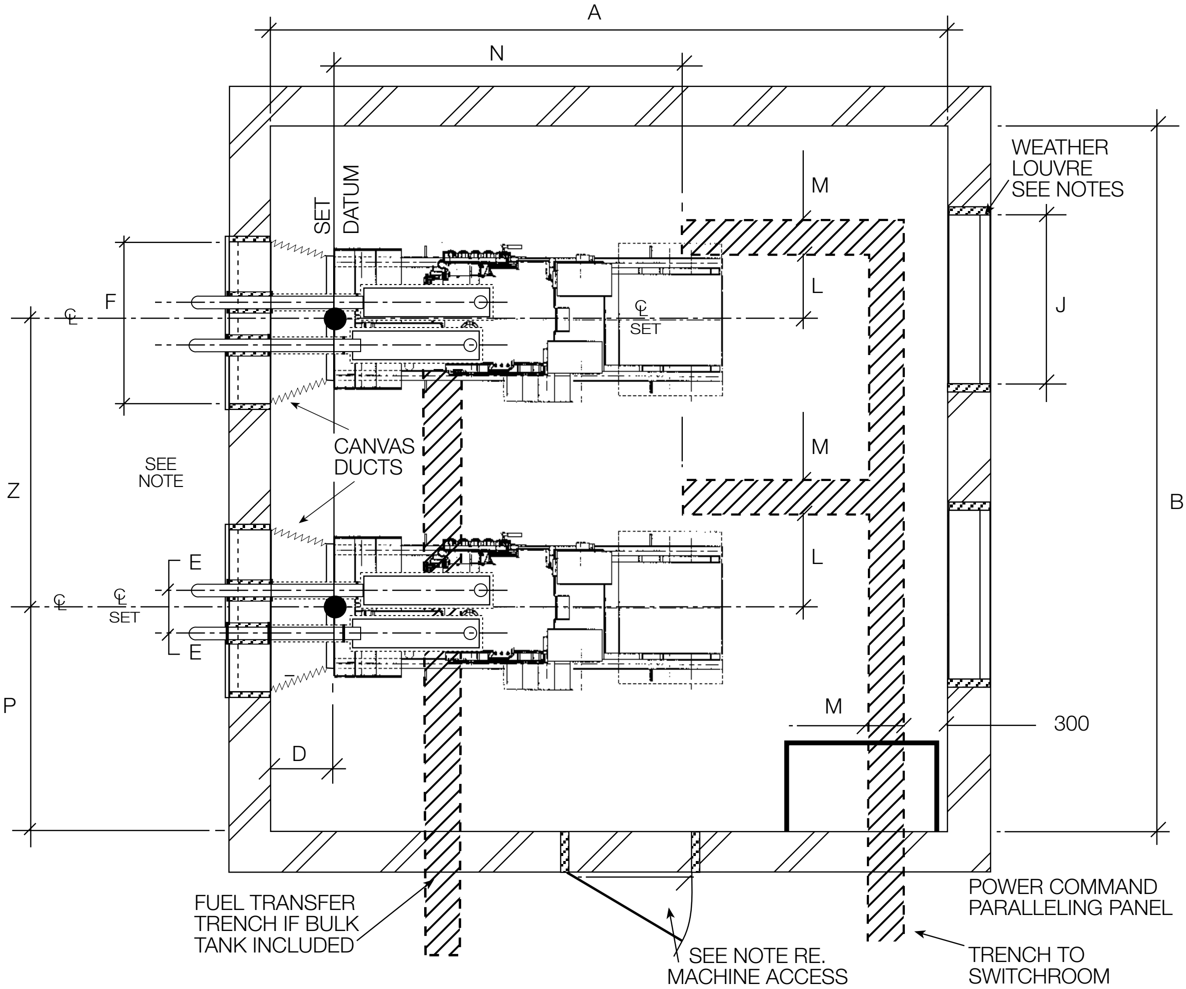
1) **Before finalising the generator room layout design please ensure you read the guidance notes.**

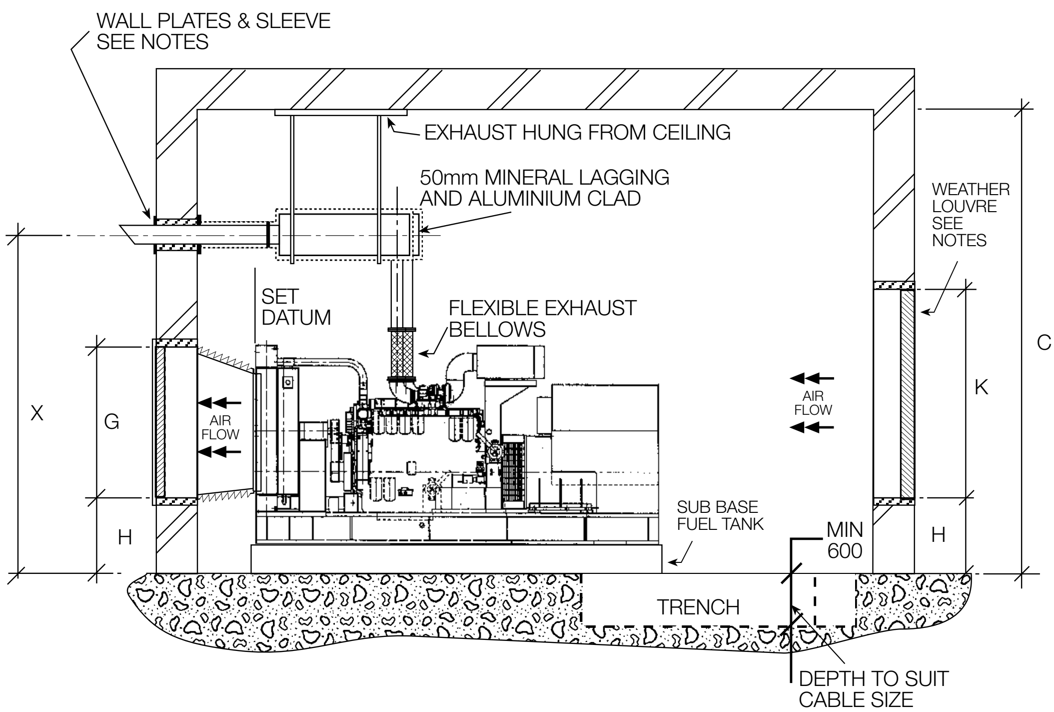
2) **The QSK60 TA Luft engines are fitted with remote radiators, the room inlet louvre would be fitted with pressurisation fan to cater for the engine heat radiated to the room, aspiration air and the alternator cooling air flow as detailed on the data sheet.**

Power Generation

Cummins Generating Sets 575 - 2000 kVA

Room layout for 2 Set installation **without** Acoustic Treatment





ROOM WITH **TWO** GENERATORS INSTALLED.

50HZ CUMMINS ENGINE POWERED **575 kVA - 1875 kVA** GENERATING SETS

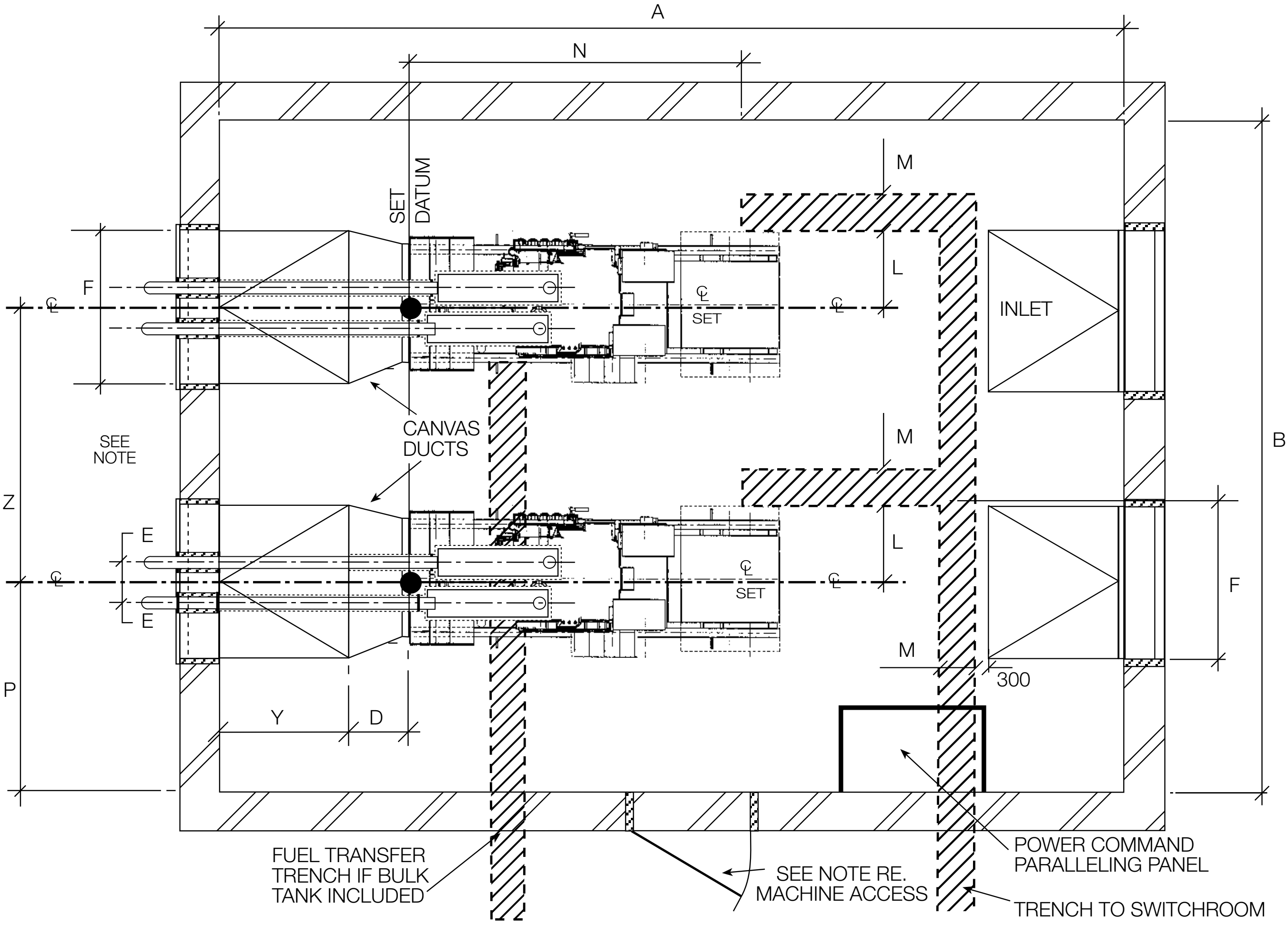
WITH ACOUSTIC TREATMENT.

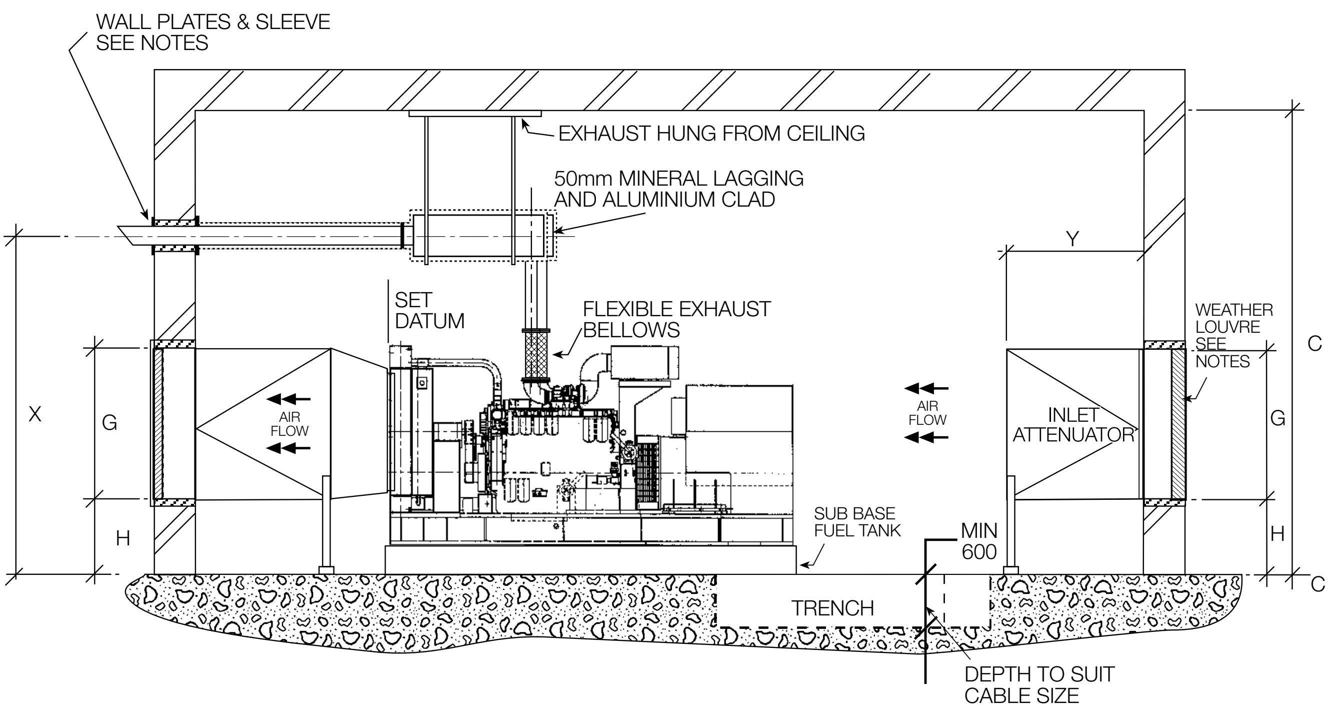
Prime Rating KVA	Type of ENGINE	TA Luft	Generator Model	Room dimensions			Positions			Exhaust		Attenuator Dimensions			Uplift	Cable trench position			
				Length A	width B	height C	apart Z	back D	set C/L P	Offset E	Height X	F	Y	G	H	L	M	N	
575	VTA28G5		460DFGA	9000	6700	3450	2450	400	2575	400	2950	1500	1800	2000	400	775	500	3500	
640	VTA28G5		512DFGB	9000	6700	3450	2450	400	2575	400	2950	1500	1800	2000	400	775	500	3500	
750	VTA28G6		600DFGD	9000	6700	3450	2450	400	2575	400	2950	1500	1800	2000	400	775	500	3500	
725	QST30G1	4g	580DFHA	9000	7080	3700	2640	500	2620	400	3150	2400	1500	2400	400	920	500	3900	
800	QST30G2	4g	640DFHB	9000	7080	3700	2640	500	2620	400	3150	2400	1500	2400	400	920	500	3900	
939	QST30G3		751DFHC	9000	7080	3700	2640	500	2620	400	3150	2400	1500	2400	400	920	500	3900	
1000	QST30G4		800DFHD	9050	7080	3800	2640	500	2620	450	3150	2700	1500	2400	200	920	500	4200	
725	QST30G6	2g	580DFHE	9000	7080	3700	2640	500	2620	400	3150	2400	1500	2400	400	920	500	3900	
800	QST30G7	2g	640DFHF	9000	7080	3700	2640	500	2620	400	3150	2400	1500	2400	400	920	500	3900	
939	QST30G8	2g	751DFHG	9000	7080	3700	2640	500	2620	400	3150	2400	1500	2400	400	920	500	3900	
936	KTA38G3		748DFJC	10100	7400	3800	2800	500	2700	450	3100	1950	2100	2200	200	920	500	3655	
1016	KTA38G5		815DFJD	10100	7400	3800	2800	500	2700	500	3100	1950	2100	2200	200	920	600	3655	
1256	KTA50G3		1005DFLC	10960	7400	3800	2800	500	2700	450	3100	1950	2100	2200	200	920	600	5000	
1405	KTA50G8		1125DFLE	12300	7800	4500	3000	600	2800	500	3500	2450	2400	2600	200	920	600	5700	
1500	KTA50GS8		1200DFLF	12300	7800	4500	3000	600	2800	500	3500	2450	2400	2600	200	920	600	5700	
1256	KTA50G6	4g	1005DFLG	10960	7400	3800	2800	500	2700	450	3100	1950	2100	2200	200	920	600	5000	
1256	KTA50G7	2g	1005DFLH	10960	7400	3800	2800	500	2700	450	3100	1950	2100	2200	200	920	600	5000	
1875	QSK60G3		1500DQKC	13250	8800	4500	3500	600	3050	693	3800	2800	2700	2600	325	645	600	4805	
2000	QSK60G4		1600DQKD	13250	8800	4600	3500	600	3050	693	3900	3150	2700	3100	250	645	600	5800	
1875	QSK60G3	2g	1500DQKE	11800	7600	4500	3000	800	2800	693	3800	2700	1800	2500	325	645	600	3800	Note 4
2000	QSK60GS3	2g	1600DQKF	11800	7600	4500	3000	800	2800	693	3800	2700	1800	2600	325	645	600	3800	Note 4

1) **Before finalising the generator room layout design please ensure you read the guidance notes.**
2) **The attenuator dimensions indicated are based on 100mm. Airways and 200mm. Acoustic modules.**
3) **In free field conditions we would expect this treatment to achieve 85dBA at 1 metre.**
4) **The QSK 60 TA Luft engines are fitted with remote radiators, the room inlet attenuator would be fitted with a room pressurisation fan to cater for engine heat radiated to the room, aspiration air and the alternator cooling air flow as indicated on the data sheet.**

Cummins Generating Sets 575 - 2000 kVA

Room layout for 2 Set installation with Acoustic Treatment





Recommended Room Sizes

Power Generation

ROOM WITH **THREE** GENERATORS INSTALLED.
50HZ CUMMINS ENGINE POWERED **575 kVA - 2000 kVA** GENERATING SETS **WITH** ACOUSTIC TREATMENT.

Prime Rating KVA	Type of ENGINE	TA Luft	Generator Model	Room dimensions Length A	Room dimensions width B	Room dimensions height C	Positions apart Z	Positions back D	Positions set C/L P	Exhaust Offset E	Exhaust Height X	Attenuator Dimensions F	Attenuator Dimensions Y	Attenuator Dimensions G	Uplift H	Cable trench position L	Cable trench position M	Cable trench position N	
575	VTA28G5		460DFGA	9300	9150	3450	2450	400	2575	400	2950	1500	1950	2000	400	775	500	3500	
640	VTA28G5		512DFGB	9300	9150	3450	2450	400	2575	400	2950	1500	1950	2000	400	775	500	3500	
750	VTA28G6		600DFGD	9300	9150	3450	2450	400	2575	400	2950	1500	1950	2000	400	775	500	3500	
725	QST30G1	4g	580DFHA	9300	9720	3700	2640	400	2620	400	3150	2400	1650	2400	400	920	500	3900	
800	QST30G2	4g	640DFHB	9300	9720	3700	2640	400	2620	400	3150	2400	1650	2400	400	920	500	3900	
939	QST30G3		751DFHC	9300	9720	3700	2640	400	2620	400	3150	2400	1650	2400	400	920	500	3900	
1000	QST30G4		800DFHD	9350	9720	3800	2640	450	2620	450	3150	2700	1650	2400	200	920	500	4200	
725	QST30G6	2g	580DFHE	9300	9720	3700	2640	400	2620	400	3150	2400	1650	2400	400	920	500	3900	
800	QST30G7	2g	640DFHF	9300	9720	3700	2640	400	2620	400	3150	2400	1650	2400	400	920	500	3900	
939	QST30G8	2g	751DFHG	9300	9720	3700	2640	400	2620	400	3150	2400	1650	2400	400	920	500	3900	
936	KTA38G3		748DFJC	10400	10200	3800	2800	450	2700	450	3100	1950	2000	2200	200	920	500	3655	
1016	KTA38G3		815DFJD	10400	10200	3800	2800	500	2700	450	3100	1950	2000	2200	200	920	600	3655	
1256	KTA50G3		1005DFLC	11260	10200	3800	2800	450	2700	450	3100	1950	2250	2200	200	920	600	5000	
1405	KTA50G8		1125DFLE	12600	10800	4500	3000	500	2800	500	3500	2450	2550	2600	200	920	600	5700	
1500	KTA50GS8		1200DFLF	12600	10800	4500	3000	500	2800	500	3500	2450	2550	2600	200	920	600	5700	
1256	KTA50G6	4g	1005DFLG	11260	10200	3800	2800	450	2700	450	3100	1950	2250	2200	200	920	600	5000	
1256	KTA50G7	2g	1005DFLH	11260	10200	3800	2800	450	2700	450	3100	1950	2250	2200	200	920	600	5000	
1875	QSK60G3		1500DQKC	13550	12300	4500	3500	600	3050	693	3800	2800	2850	2600	325	645	600	4805	
2000	QSK60G4		1600DQKD	13550	12300	4600	3500	600	3050	693	3920	3150	2850	3100	250	645	600	5000	
1875	QSK60G3	2g	1500DQKE	12100	10600	4500	3000	800	2800	693	3800	2700	1950	2500	325	645	600	3800	Note 4
2000	QSK60GS3	2g	1600DQKF	12100	10600	4500	3000	800	2800	693	3800	2700	1950	2600	325	645	600	3800	Note 4

ROOM WITH **FOUR** GENERATORS INSTALLED.
50HZ CUMMINS ENGINE POWERED **575 kVA - 2000 kVA** GENERATING SETS **WITH** ACOUSTIC TREATMENT.

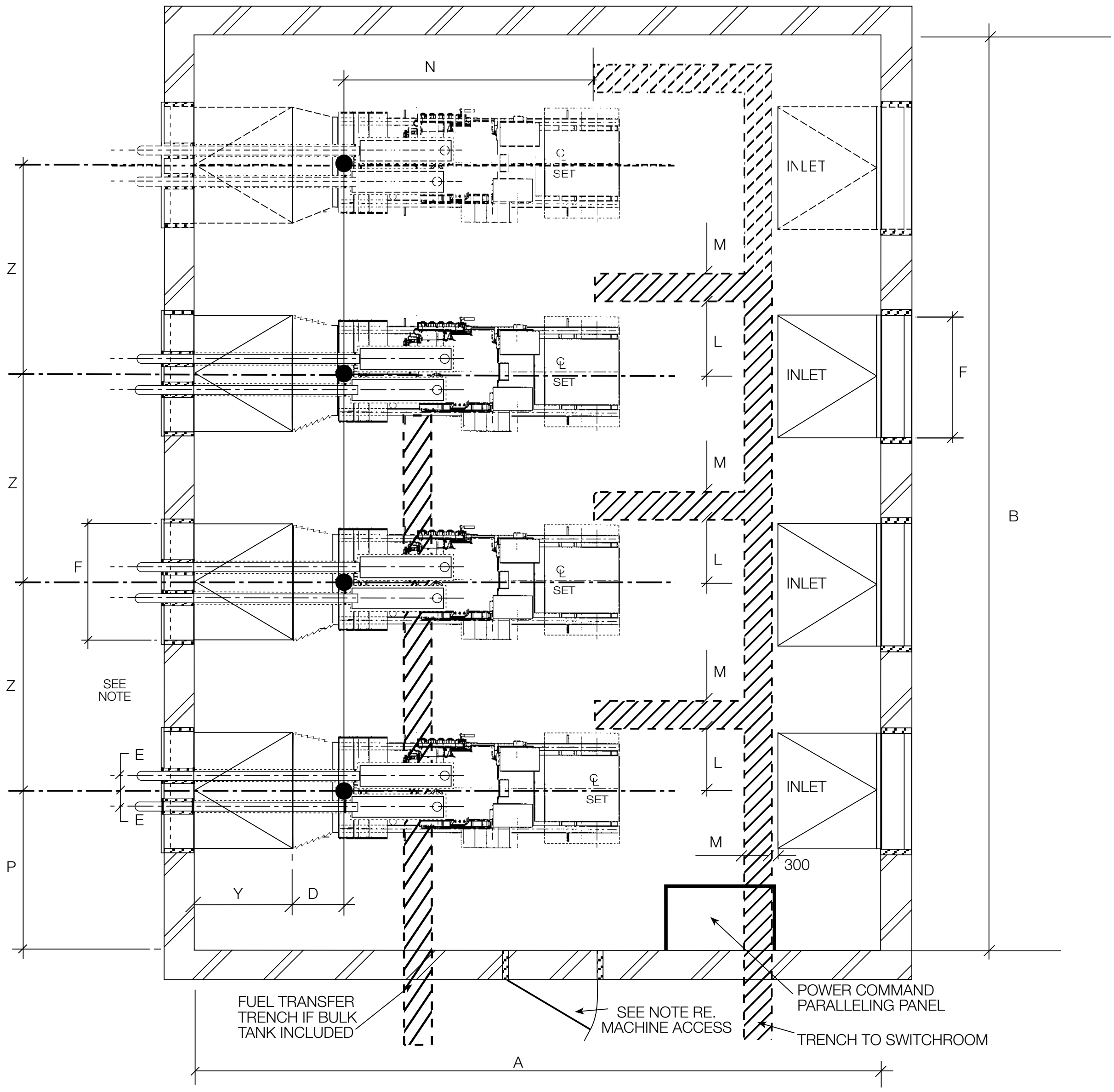
Prime Rating KVA	Type of ENGINE	TA Luft	Generator Model	Room dimensions Length A	Room dimensions width B	Room dimensions height C	Positions apart Z	Positions back D	Positions set C/L P	Exhaust Offset E	Exhaust Height X	Attenuator Dimensions F	Attenuator Dimensions Y	Attenuator Dimensions G	Uplift H	Cable trench position L	Cable trench position M	Cable trench position N	
575	VTA28G5		460DFGA	9600	11600	3450	2450	400	2575	400	2950	1500	2100	2000	400	775	500	3500	
640	VTA28G5		512DFGB	9600	11600	3450	2450	400	2575	400	2950	1500	2100	2000	400	775	500	3500	
750	VTA28G6		600DFGD	9600	11600	3450	2450	400	2575	400	2950	1500	2100	2000	400	775	500	3500	
725	QST30G1	4g	580DFHA	9600	12360	3700	2640	500	2620	400	3150	2400	1800	2400	400	920	500	3900	
800	QST30G2	4g	640DFHB	9600	12360	3700	2640	500	2620	400	3150	2400	1800	2400	400	920	500	3900	
939	QST30G3		751DFHC	9600	12360	3700	2640	500	2620	400	3150	2400	1800	2400	400	920	500	3900	
1000	QST30G4		800DFHD	9650	12360	3800	2640	500	2620	450	3150	2700	1800	2400	200	920	500	4200	
725	QST30G6	2g	580DFHA	9600	12360	3700	2640	500	2620	400	3150	2400	1800	2400	400	920	500	3900	
800	QST30G7	2g	640DFHB	9600	12360	3700	2640	500	2620	400	3150	2400	1800	2400	400	920	500	3900	
939	QST30G8	2g	751DFHC	9600	12360	3700	2640	500	2620	400	3150	2400	1800	2400	400	920	500	3900	
936	KTA38G3		748DFJC	10400	13000	3800	2800	500	2700	450	3100	1950	2000	2200	200	920	500	3655	
1016	KTA38G3		815DFJD	10400	13000	3800	2800	500	2700	450	3100	1950	2000	2200	200	920	600	3655	
1256	KTA50G3		1005DFLC	11560	13000	3800	2800	500	2700	450	3100	1950	2400	2200	200	920	600	5000	
1405	KTA50G8		1125DFLE	12900	13800	4500	3000	600	2800	500	3500	2450	2700	2600	200	920	600	5700	
1500	KTA50GS8		1200DFLF	12900	13800	4500	3000	600	2800	500	3500	2450	2700	2600	200	920	600	5700	
1256	KTA50G6	4g	1005DFLG	11560	13000	3800	2800	500	2700	450	3100	1950	2400	2200	200	920	600	5000	
1256	KTA50G7	2g	1005DFLH	11560	13000	3800	2800	500	2700	450	3100	1950	2400	2200	200	920	600	5000	
1875	QSK60G3		1500DQKC	13850	15800	4500	3500	600	3050	693	3800	2800	3000	2600	325	645	600	4805	
2000	QSK60G4		1600DQKD	13850	15800	4600	3500	600	3050	693	3920	3150	3000	3100	250	645	600	5800	
1875	QSK60G3	2g	1500DQKE	12400	13600	4500	3000	800	2800	693	3800	2700	2100	2500	325	645	600	3800	Note 4
2000	QSK60GS3	2g	1600DQKF	12400	13600	4500	3000	800	2800	693	3800	2700	2100	2600	325	645	600	3800	Note 4

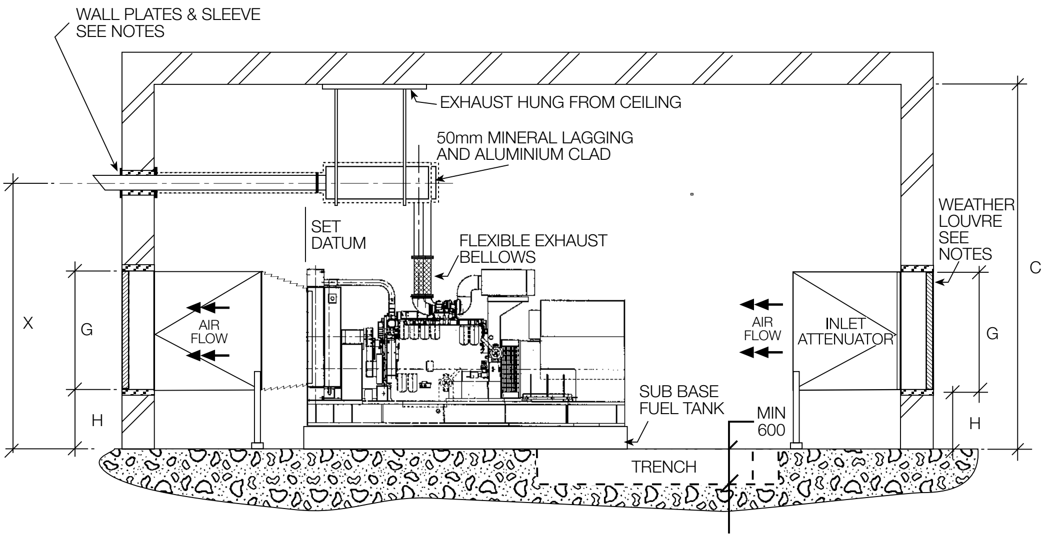
1) **Before finalising the generator room layout design please ensure you read the guidance notes.**
2) **The attenuator dimensions indicated are based on 100mm. Airways and 200mm. Acoustic modules.**
3) **In free field conditions we would expect this treatment to achieve 85dBA at 1 metre.**
4) **The QSK60 TA Luft engines are fitted with remote radiators, the room inlet attenuator would be fitted with a room pressurisation fan to cater for engine heat radiated to room, aspiration air and the alternator cooling air flow as indicated on the data sheet.**

Cummins Power Generation

Cummins Generating Sets 575 - 2000 kVA (up to 4.5 MW installation)

Room layout for Multiple Set installation **with Acoustic Treatment** to Achieve 85dBA @ 1 metre





Multiple Gen Set Installations

4 x 800 kVA Gen Sets in a ground level room installation with simple but effective exhaust run.

Four 1500 kVA sets with KTA50 engines running on base load operation in Saudi Arabia.

Enclosed and Roof Mounted Generating Sets

Where internal Ground Floor or Basement space is unavailable, either an adjacent outside location can be used or, providing the structure is sufficiently strong enough or can be strengthened, the flat roof area of a building can be used. Roof installations have become widely used in many towns and cities where space is of a premium. Packaged and soundproofed individual units up to 2MW each have been successfully accommodated in this manner over the last few years in many countries.

Recommendations for Roof Top and High Level Installations

Only consider when there is no ground or basement level room available or/and when the cost of high level installation – including structural work – is cheaper than normal installations.

Benefits

No air flow problems

No expensive ductwork

No lengthy exhaust runs

No problems with exhaust fume emissions

No noise problem

No space limitation problems

Disadvantages

Roof structure may have to be strengthened

Large crane required

Possible road closure

Planning permission required

Longer cable runs

Limited fuel storage

Unusual roof top (15 storeys high) installation for three 1500 kVA sets demands re-assembly of sets using rails and specially built A frame for transport and lifting.

Roof structure

The structure of the roof area must be suitable for an installation. The strength of the flooring structure is vital. Should the floor be found unsuitable the problem can often be overcome by installing a floating floor of structural steel platforms across the building's main columns.

Vibrations

Transmitted vibration through the building can be substantially reduced by:

(a) Having built-in anti-vibration units within the design of the generating set. This eliminates up to 75-80% of transmitted engine vibrations.

(b) Installing additional vibration dampers between the generating set chassis and the roof is possible but requires specialist design to avoid resonance. This combination eliminates up to 98% of the vibration.

(c) With generators over 1MW it may also be desirable to include a concrete slab base which in turn is resiliently mounted to eliminate vibration through the building.

While all these methods have been used on various buildings the majority have been found quite satisfactorily with the normal built-in anti-vibration system provided as standard.

Where possible a packaged set, 300 kVA as shown in picture, on a base frame provides a faster installation. Silenced enclosure drops over unit. Note prepared steel structure support base.

Noise

All generating sets installed at roof level have soundproof enclosures fitted or are installed in rooms with full inlet and outlet sound attenuators and twin residential silencers. Heavy duty soundproof enclosures can reduce noise levels by 15 to 30dB(A) and limited only by budget or local noise regulations. A sound level of 75dB(A) at 1 metre is a substantial reduction and equal to a normal office environment.

Accessibility

The final roof location for the generator must take into account access and cranage requirements. For example, a 100 ton mobile crane with a 30m (100ft.) radius will only lift approximately 5 tons. Lifting vertically is no problem but positioning a large generator 30 or 40 metres from the building's edge will place a heavy stress on the crane's jib. The lifting capacity is therefore limited by the required reach or radius. To illustrate, in order to lift a 1.3MW set weighing 22 tons onto an eight storey roof and place it 14 metres from the edge, it was found necessary to use a 250 ton crane.

In many cases because of the weight and radius problem coupled with ground and street accessibility, it is necessary to dismantle the generating set – sometimes into five or six loads – engine, alternator, chassis, control cubicle, soundproof enclosure and radiator. Reassembly should be under supervision of Cummins Power Generation technicians so as not to invalidate the warranty.

Although this procedure may take a little longer in terms of crane hire, dismantling and re-assembling, the smaller crane size will cost less and overall the total installation price is unlikely to be greatly changed.

It is possible to use a Helicopter, although there will be weight and flying limitations, and this can be very cost effective if all the restrictions can be overcome. At least 2 tons can be lifted and although this invariably means dismantling the generator the cost of a helicopter will only be a fifth of the cost of an equivalent sized crane.

In order to use a helicopter, it must have a 'safe' dropping area to fly over if it has to carry the equipment any distance. Alternatively, it has to be able to lift from a 'free and safe' area in order to land equipment on a roof. The helicopter hire company will advise you and seek flying permission from the Aviation Authorities or the whole job can be left to the generating set manufacturer.

Colour and Planning Permission

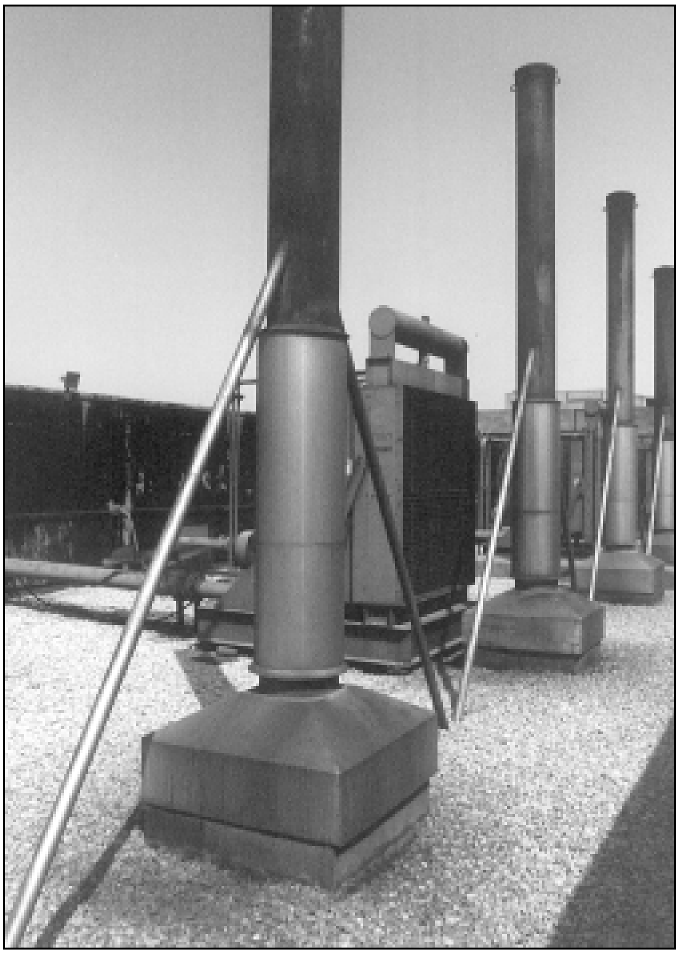
As you will almost certainly be changing the shape of the skyline, Planning Permission will have to be sought. Many area authorities stipulate that existing skylines cannot be altered, whilst others specify that soundproof enclosures must blend with the skyline.

It is the Client's or Agent's responsibility to acquire Planning Permission.

Fuel Supply

A very limited amount of fuel storage is permitted at roof level. Weight and Fire considerations are paramount. In general, a 'day tank' for each set is permitted but even this may be severely limited (to 450 litres (100 gallons)) by some Local Planning and Fire Authorities. It is essential to obtain full approval from the Authorities for the fuel system.

Your bulk fuel storage will be subject to the local authority Fire Regulations governing all safety aspects. Fuel will be pumped up to the day service tank – which will normally have a high and low float level regulator fitted to control the pump motor. It is essential that the day tank has adequately sized overflow pipework – certainly equal to the supply pipe size if not larger – which returns to the bulk fuel tank.



Roof mounted remote radiators for four 1000 kVA sets and extended exhaust tail pipes where space and air flow is restricted.

Exhaust and Air Flows

Few problems are likely to be encountered with either exhaust or air flows at roof top levels and this is a major advantage with this type of location. If the roof level is below adjoining buildings, the direction of the exhaust system should be carefully sited – and prevailing winds taken into consideration. A vertical stack with a weathercap is occasionally recommended if offices with open windows are in close proximity.

Air flow inlet areas should be kept clear of any obstructions likely to restrict the air intake passage. Air outlet is unlikely to cause any problems but again prevailing winds should be considered as gale force winds blowing straight into the air outlet may cause restriction. As a solution use angled outlet louvres to overcome this problem.

Cabling

Probably the most expensive item as a result of roof top installation. It is recommended that the control cubicle containing the changeover contractors be located as close to the building's incoming public power supply as possible. This will limit one of your main power cable runs to the minimum.

Control cables will still have to be run up to the roof level but these are small core cables. It is recommended that the generator's control system, sensing and instrumentation, be retained in close proximity to the installed generator. Output cable from the generator should use existing service ducting where possible.

Police and Local Authority

Invariably, the use of heavy vehicles and large cranes will mean road closures, particularly in densely populated urban areas. Notifying the Police and local authorities well in advance is recommended and their co-operation encouraged. In busy city areas, traffic diversions are essential – it also means delivery and installation is only possible at weekends.

Two roof mounted super-silenced 1000 KVA sets with extended attenuators for a superstore provide a clean installation.

Check List for Roof Top Installations

(1) Height of building.

(2) Area of installation.

(3) Position of generator/Adjacent Plant.

(4) Distance from building edge to position of set.

(5) Strength of buildings roof. Reinforced slabs or steel beams?

(6) Sound insulation of roof necessary? – e.g.: with additional anti-vibration units, special mats, etc.

(7) Access to roof for personal, and maintenance (drums of oil, etc).

(8) Size of crane required.

(9) Weight of Gen Set, enclosures, control panels.

(10) Can the complete set be lifted or will it have to be dismantled and reassembled on roof?

(11) Length of jib necessary?

(12) Maximum height necessary?

(13) Check area of hard standing/concrete for cranes supports.

(14) Check access for mobile crane and restrictions.

(15) Can the installation be carried out in daylight or does it have to be at night? Is road closure necessary?

(16) Check day to install crane and lifting operations – weekdays or weekends?

(17) Position for exhaust direction – avoiding fumes in windows, etc, direction of air flow across generator set.

(18) Position of cables and fuel feeds.

Twin 1875 Kva generating sets with Cummins QSK60G3 engines installed on a 10 story roof top installation for Data Computer Centre. Silenced to 75 db(A) at 1 m, each set weighed 26,000 kg with a control panel container weighing 700kg. Congested City Centre meant the installation had to be carried out at night.

Project Guide

For Full Technical Date refer to Section G – Ref. pages G36 to G41

Recommended room sizes for Natural Gas Generating Sets 1100 to 1750 kW

Basic Power Station <u>with</u> sound attenuation treatment

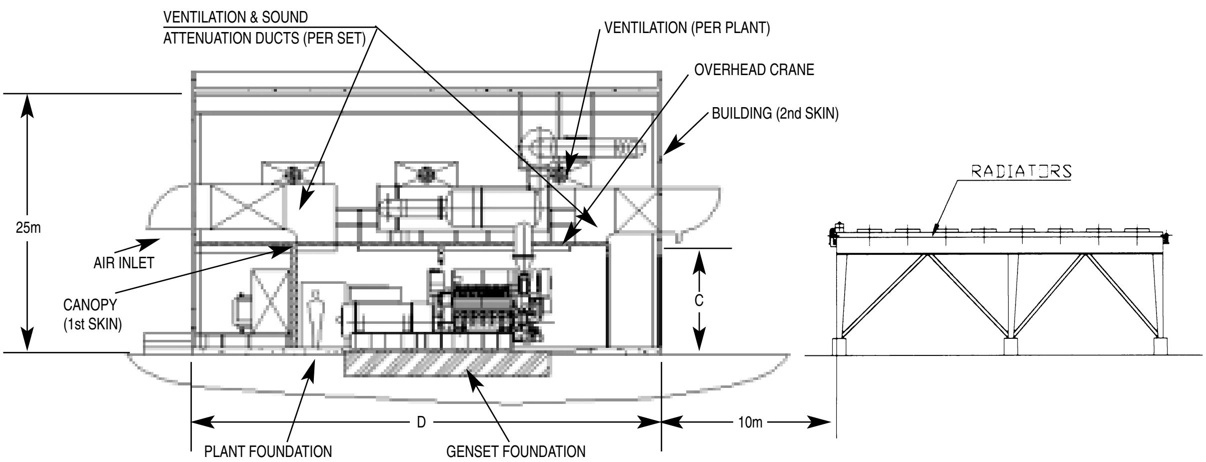
General

Cummins Power Generation will develop power stations from green field sites, taking responsibility for the preparation of the site, including all civil works from slab foundations, to cable and pipe trenching. The type of housing for the equipment depends on space constrictions, speed of putting into operation and the time-span of the project. A short term project with tight space restraints would benefit from a containerised solution, whereas the extended project term with lots of space would demand a brick or steel clad building.

Example of range (silenced installations)

50Hz Continuous Rating	Gen Set Model	Engine Model	Length A Set Room m	Width Set Room m	Height C m	O/Length D m	60Hz Continuous Rating	Length Set m	Width Set m	Approx Height Set m	Weight (tons)	BMEP (bar)
1370 kW	GQMA	QSV81G	10	5.7	3.4	14	1100 kW	5.4	1.7	2.6	19.0*	14
1570 kW	GQMB	QSV81G	10	5.7	3.4	14	–	–	–	–	–	16
1540 kW	GQNA	QSV91G	10	5.7	3.4	14	1250kW	5.6	1.7	2.6	20.5*	14
1750 kW	GQNB	QSV91G	10	5.7	3.4	14	1750kW	5.6	1.7	2.6	22*	16

*Refer to Section G for specific weights.



Power station with silencing treatment and designed for tropical climates and continuous operation.

Noise Attenuation

This power plant room is designed for temperate climates or hot climate countries. Enhanced for sound attenuation the residual noise level is 50 dBA @ 50 metres.

Maintenance areas are provided around the generator sets, providing the ability to repair each generator set individually without breakout noise.

The external structure of the building may be made of steel with insulating material or of concrete. The walls and the roof should be treated with mineral fibre in-fill and the inlet and discharge air-pass through attenuators. Doors should be padded with mineral fibre.

Sufficiently large maintenance doors should be provided to allow generator set removal from the building.

Combustion air is taken into the generator set room from outside by a fan through a sound trap. The air outlet is soundproofed and the exhaust line is equipped with two high efficiency residential silencers.

Power cables may be routed in trenches or on overhead cable trays.

Refer to the Gas Power Plant Project Guide Manual for additional details.

Back to Index

Power Plant Buildings (General)

This section indicates the basic principles of erecting a steel or brick building. It is not intended as a definitive guide to building construction. The typical layout drawings contained within this section are meant for guidance purposes only. The design and layout of the building and its contents would be job specific.

Building Layout

The building is largely a reflection of the processes that exist inside it. The size will reflect the layout of the hardware, giving due consideration to the space required to install and maintain it and to provide adequate access for installation and removal for replacement and repair.

The height should allow sufficient room for the suspension of exhaust silencers and pipework, and the trays or ladder racking for cables if trenching is not appropriate.

The routing of water, fuel, lubricating oil and gas pipes will also have to be planned where they cannot be placed in a covered trench.

The movement of ventilation and aspiration air should be carefully considered so that the point of introduction and discharge ensures the heat generated by the hardware is dispelled without short circuit. The air velocity, volume and acceptable temperature rise will determine the size of the apertures and the number and rating of the ventilation fans.

Noise control treatment will be required wherever a breakout can occur. The walls and roof section should be treated with mineral fibre in-fill and the inlet and discharge air will pass through attenuation units. Doors will also be padded with mineral fibre.

One of six 18 cylinder natural gas engine powered Cummins QSV91G CHP Generating sets for an installation producing 1750 kWe and 2000 kW of heat per set.

Generator set foundations

The foundation slab should be able to support the static weight of the generator set with the weight distributed evenly across the isolators. If isolators are not used, the slab weight should be 125% of the generator set weight.

In the following table, dimensions “A” and “B” should exceed the dimensions of the generator set by 300mm.

The depth of the concrete base will depend on the composition of the soil. Firm, level soil, gravel or rock provides satisfactory support. Soil such as fine clay, loose sand, or sand near the ground water level is particularly unstable under dynamic loads and requires a more substantial foundation.

The area of load bearing support is adjusted to according to the surface material. To determine the pressure (P) exerted by the generator set, divide the total wet weight (W) by the total surface area (A).

$$P(\text{psi}) = \frac{W\ (\text{kgs})}{A\ \ \ (\text{mm})}$$

The pressure imposed by the generator set weight must be less than the load carrying capacity of the supporting material.

Seasonal and weather changes adversely affect mounting surfaces. Soil changes considerably while freezing and thawing. To avoid movement from seasonal change, extend foundations below the frost line.

Concrete Base

The base concrete slab should be designed to accept all the static and dynamic loads imposed by the generator set and all the associated plant equipment that is required. The slab must also be adequately supported by the soil or a robust structure such that it remains level.

Engine type	Weight of the genset (kg) in operation	Dimensions of the foundation (mm) (concrete spec. weight : 2.4		
		A	B	C
QSV 81G	20.500	6,500	2,000	700
QSV 91G	22,000	7,000	2,000	700

Dimensions of foundations are given as a guide only. Refer to factory for certified data on specific installations.

Recommended buildings room sizes for Natural Gas generating sets 1100 to 1750 kW

Basic Power Station <u>without</u> sound attenuation treatment

Main features

This power plant is designed for cost effective installation, providing fast commissioning and simplified servicing.

The whole building should be erected on an elevated slab to prevent flooding. The structure of the building can be made of corrugated steel or brick. Fans should be installed on the front of the building and push air towards the engine, transformer and generator. Room ventilation may be by natural convection through large inlet and outlet louvres, if ambient temperature is below 35ºC. Air exits are normally on the roof but take care that louvres are not facing main winds.

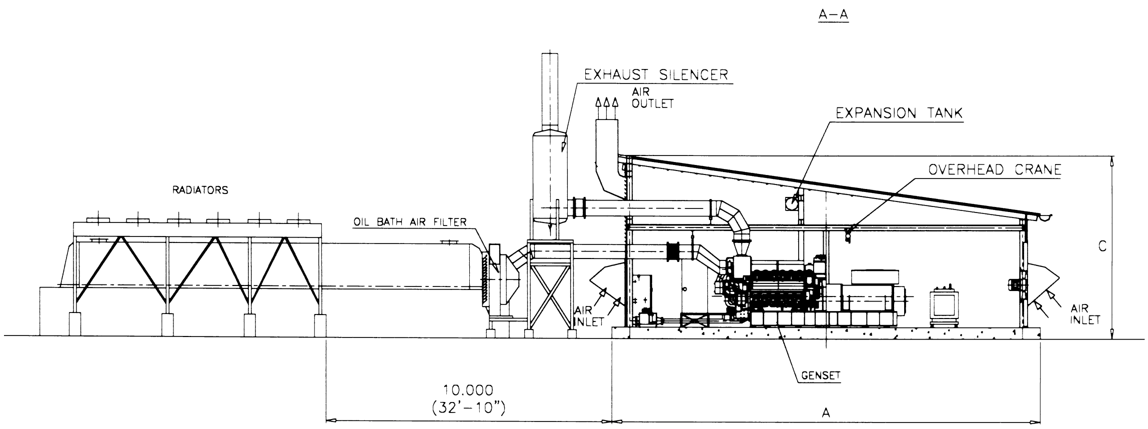
Mechanical auxiliaries should be positioned near the front end of the engine to reduce piping runs.

An oil bath air filter, placed outdoors can take in air at a high level to prevent dust and exhaust hot air recirculating.

The electrical room should be built in masonry to prevent temperature changes and condensation effects. By placing it in the middle of the building it will shorten power and control lines. Power cables may be routed in trenches or on overhead cable trays.

Radiators are normally grouped together to prevent hot air recirculating. It is recommended to place them 10 metres (30 ft) from the power station.

50Hz Continous Rating	Engine Model	A m	B (see B33) m	C m	Number of gensets	60Hz Continous Rating
1370 kW GQMA	QSV81G	15	5.5	7.0	2 to 8	1100 kW GQMA
1570 kW GQMB	QSV81G	15	5.5	7.0	2 to 8	–
1540 kW GQNA	QSV91G	15	5.5	7.0	2 to 8	1250 kW GQNA
1750 kW GQNB	QSV91G	15	5.5	7.0	2 to 8	1750 kW GQNB



Building Regulations

Planning and building legislation varies throughout the world. However the principles behind such legislation are almost always the same and have therefore been given due consideration. These principles are:

– Location suitability and environmental friendliness.

The "zoning plan" for a particular area dictates the function and general appearance (size and height, etc.) of buildings in the area.

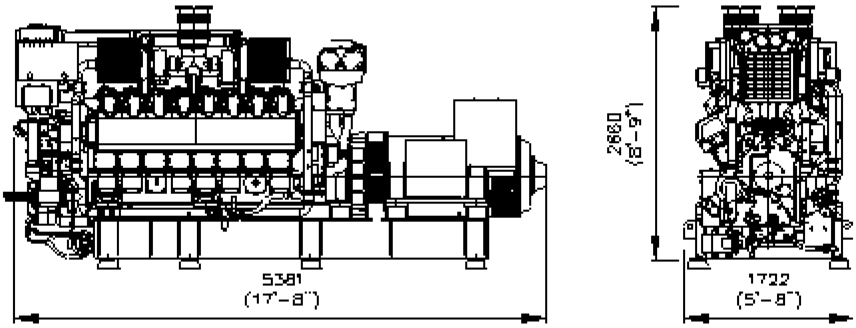
– Structural stability

The buildings structure must naturally withstand the pressures placed upon it by local conditions. Building regulations will decide the loadings that the building must be designed for under local circumstances.

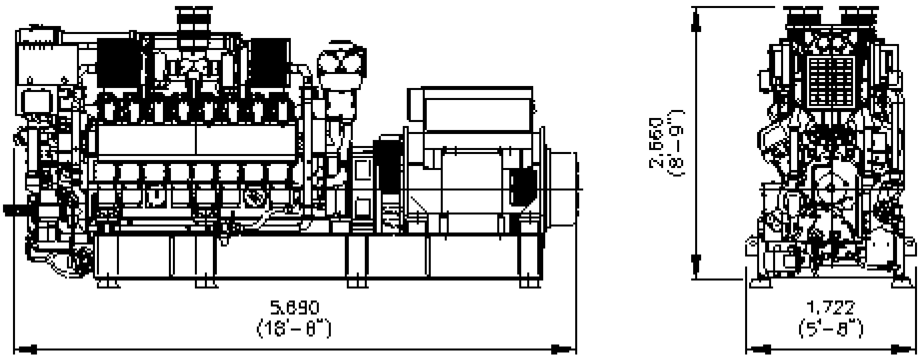
Codes throughout the world differ in respect to requirements on structural stability and therefore the final structural arrangement of the building will differ. Extreme circumstances, such as risk for earthquake, storm, require special consideration.

Generator Set Arrangement – Natural Gas Power Generation

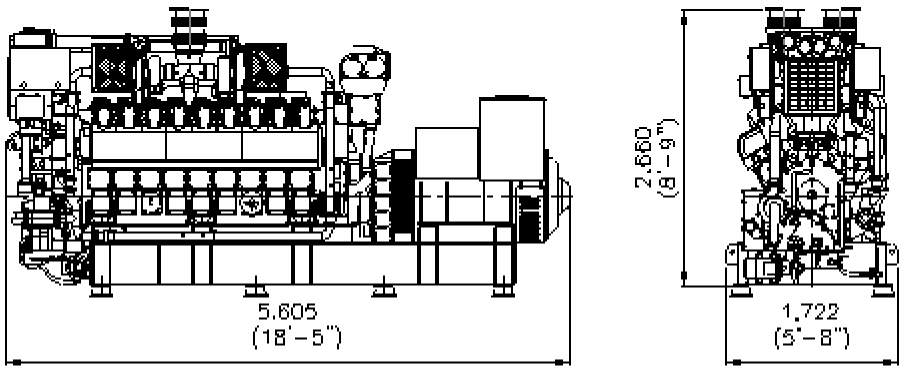
The following figures show generator set general outline dimensions as a guideline.



LV Generator powered by QSV 81G gas engines



MV Generator powered by QSV 81G gas engines



LV Generator powered by QSV 91G gas engines

LV – Low Voltage (to 440V).
MV – High Voltage (to 13.8 kV).

Natural gas

Composition of natural gas varies greatly according to the production field. Gases having composition as shown in the below given table are called natural gas. If the applied natural gas deviates from the enclosed stated, special attention must be taken for lean burn gas engine use.

Generic composition of natural gas

Gas	Formula	Content vol %
Methane	CH_4	75-99
Ethane	C_2H_6	0-5
Propane	C_3H_8	0-3
Butane	C_4H_{10}	0-2
Hydrogen	H_2	0
Carbon dioxide	CO_2	0-10
Oxygen	O_2	0-0,2
Nitrogen	N_2	0-15
Others		0-5

Gas quality requirements

To ensure the correct operation and output of the engine, the fuel gas has to meet the criteria given in the table below.

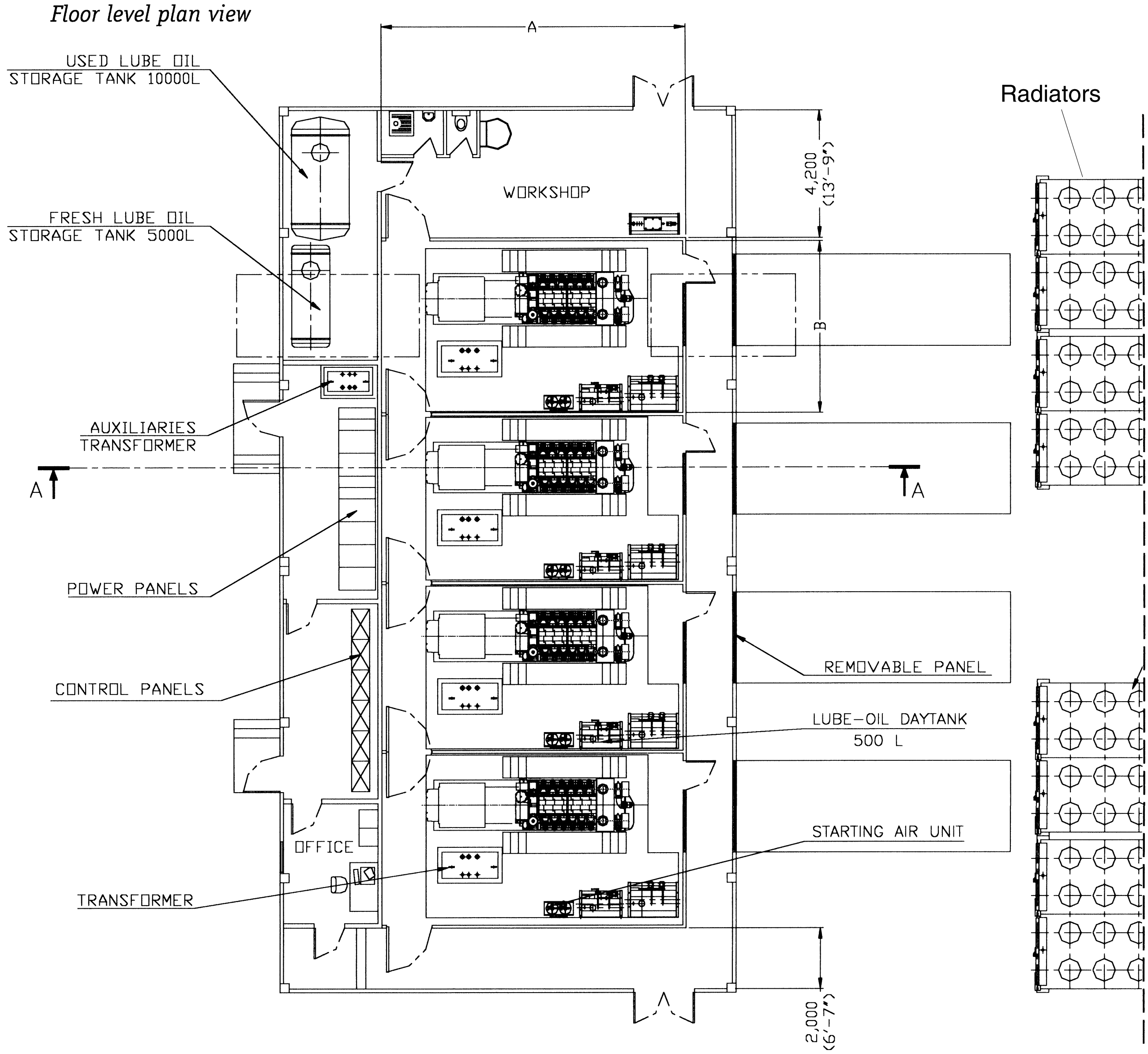
If the fuel gas does not meet the requirements the engine must be derated. Follow indications of generating set data sheet.

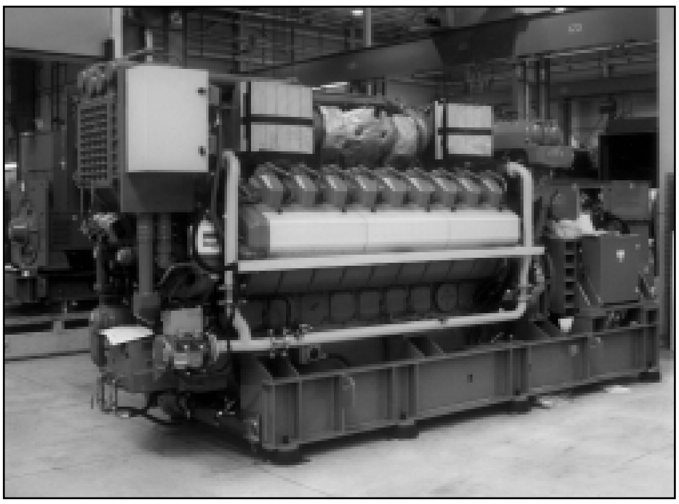
Gas	unit/formula	criteria
Gas heat value (LHV)	MJ/Nm^3	>30
Gas density	kg/Nm^3	0,7-0,9
Methane number	MN	>52
Hydrogen sulphide	H_2S	>0,01%
Max. gas temp.	°C	50

Power Generation

Multi-Set Installation – Gas Powered Generators

Floor level plan view





Model GQNB 1750 kW 18 Vee QSV91G engine.

Large Containerised Gas Powered Generating Sets

General

Containerised power plants are designed to be easily and quickly delivered all over the world, and installed in a very short time. The low sound level of a soundproofed container is 85 dB(A) at one metre distance around the container or 75 dB(A) with the supersilenced version.

Modularity

These large power plants are enclosed in two kinds of containers, one 40ft for the generating set, plus one 20ft or 40ft, air conditioned, for electrical control equipment. Radiators can be delivered separately and installed near the generator container or combined as part of the whole container package.

Step-up power transformers are situated outdoors. Prepared cables are available for interconnecting mechanical and electrical containers.

A workshop container, with air conditioning may be provided as an option.

Installation Requirements

Containerised plant is intended to permit quick installation on a paved area. Cables and pipe trenches can be provided for multiple generator sets interconnection. Slab concrete thickness should not vary more than 30 mm over the whole seating area of the generator set container but does depend upon the composition of the soil. Horizontal tolerance is 10 mm per metre. Slab strength shall be sufficient to support indicated weights only. There are no significant dynamic forces during operation.

Local scope of supply is mainly the electrical distribution system and/or switchboard.

Operating power supply needs (25 to 50kW per generator set) for preheating and starting, and fresh water delivery for the cooling circuit top-up.

Black-start containerised power plant can be provided on request.

Installation of radiators

Radiators and the cooling system form an integral part of the Cummins Containerised packaged power unit. The generators are provided with horizontal mounted roof radiators connected directly to the engine. No installation work is required. Alternatively if the specification demands radiators which are to be remote from the container unit they should be installed at ten metres distance from the generator containers, to prevent exhaust gases recirculating through the radiator. If multiple radiators are installed, it is recommended to group them, ensuring that the lateral air inlet section is equal or more than the top surface. This arrangement ensures fresh air can reach the central blowers. If these rules are followed, recirculating hot air from existing radiators will be minimised.

Paved or gravelled area should be layed under radiators, to prevent dust clogging.

Exhaust stack

Using the Cummins concept of packaged power units exhaust silencers and pipework are supplied on the roof of each container. No installation work is necessary. Alternatively if exhaust lines are grouped into a common stack, each single engine exhaust should be routed separately.

Civil works

Free areas should be provided between containers, with separate trenches for pipes and for power cables. Control and instrumentation cables may be eventually installed over the pipes, but should never be routed with power cables. Trenches shall be well drained by a large diameter free running pipe.

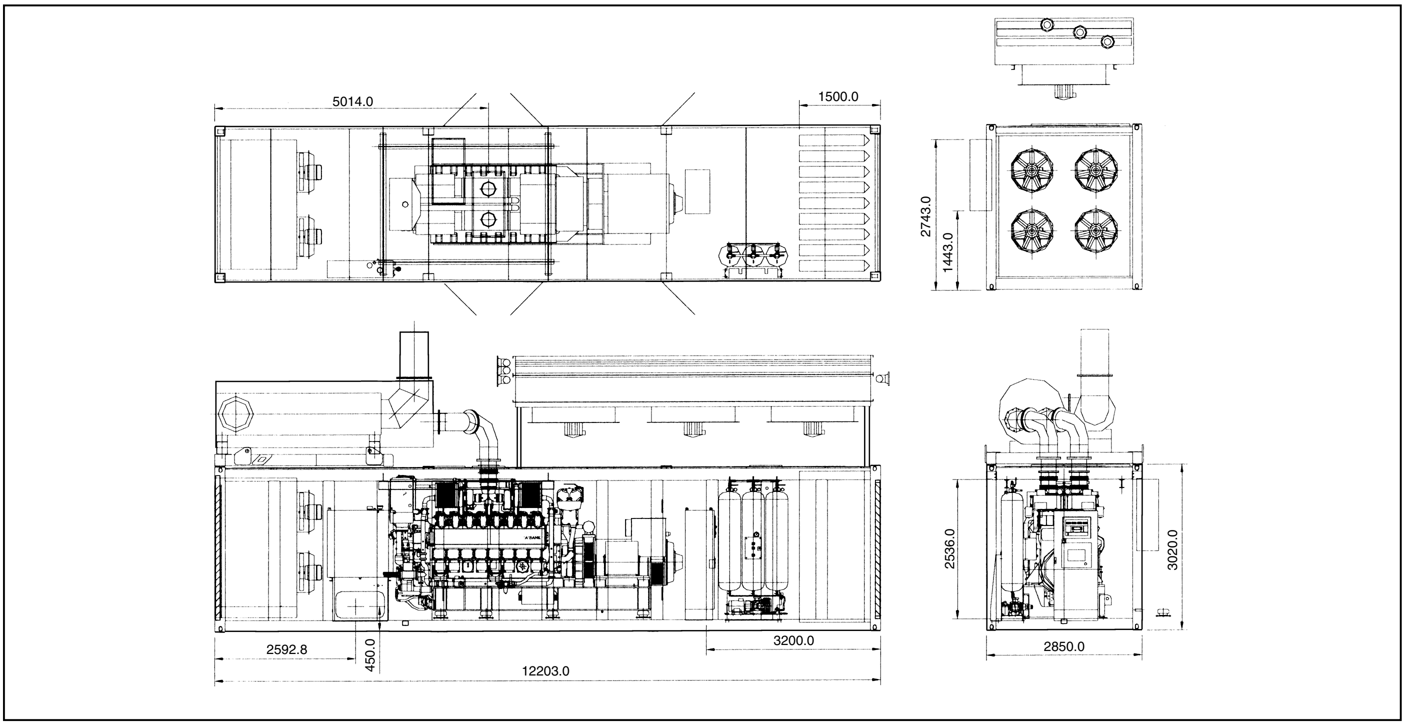
Concrete slab should be layed on a well drained area. The slab around containers must be able to support the weight of generator sets when removed from container, and the surround must provide a solid base for operating the loading cranes.

Foundations – Refer to page B31.

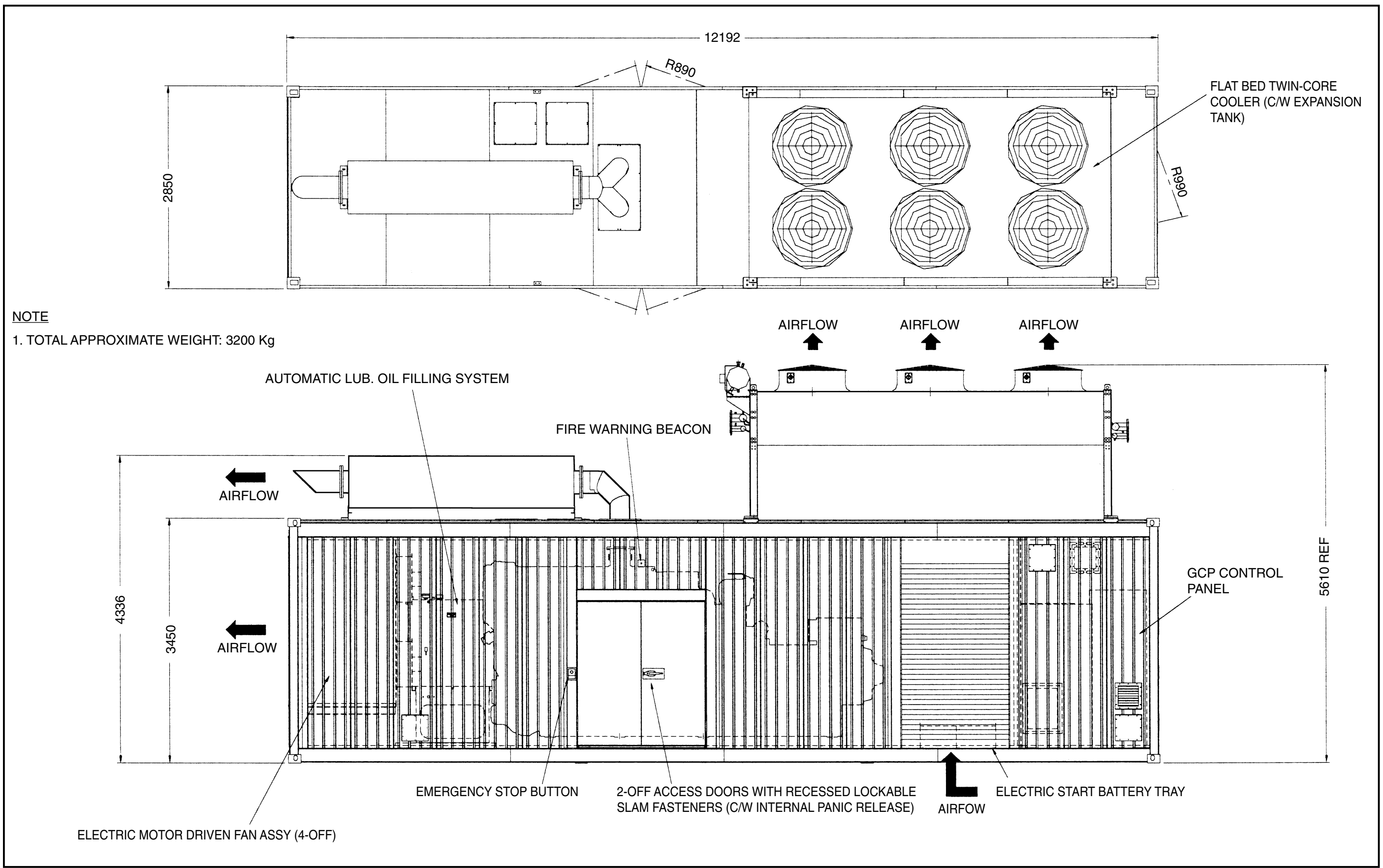
Typical 1750 kW Gas Genset Installation.

The Cummins combined/integrated containerised packaged unit. Self contained with starting system, exhaust system and radiator cooling, local or remote control facilities.

Range: 1370 to 1750 kW 50 Hz.
1100 to 1750 kW 60 Hz.



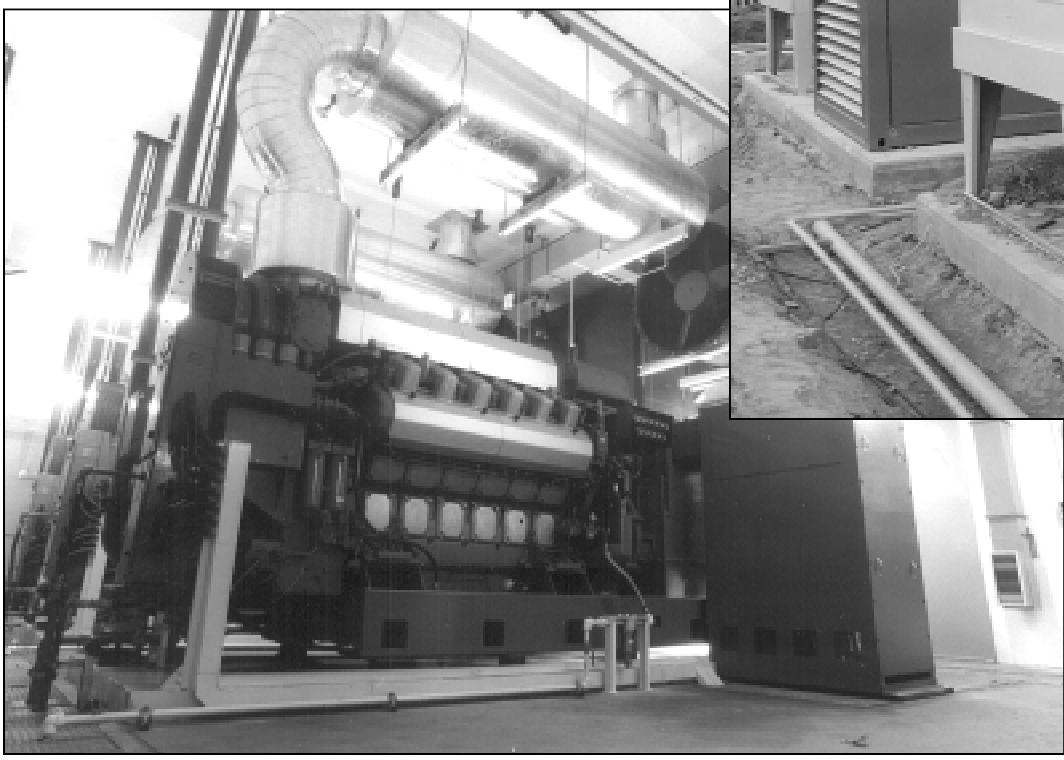
Model GQMB 1570 kW with the QSV81G Vee 16 cyl engine.



Model GQNB 1750 kW with the QSV91G Vee 18 cyl engine.

Containerised, 1.57 MW HV sets used for peak lopping duties with horizontal external cooling radiators. Whole installation silenced down to 75dB(A) at 1m and inaudible at around 50ft.

Fuel piping and auxiliary cabling runs.



Standby sets in specially prepared plant room. Note height required to accommodate large silencers.

General

Dependent upon the specific site layout, the fuel can be supplied to the engine either from:-

1. The sub-base fuel tank located under the generating set.
2. An intermediate daily service tank located within the plant room or generator enclosure, which is automatically refilled from a bulk storage tank; or
3. A bulk storage tank, provided that the outlet connection from this tank is at least 500mm higher than the base on which the generator is mounted.

Reputable fuel suppliers deliver clean, moisture free oil. Most of the dirt and water in the fuel is introduced through careless handling, dirty storage tanks or lines and poorly fitted tank covers.

The final selection of the fuel system is very much dependent upon the site layout and the relative heights of the generator and the bulk storage facility. The engine is designed to run on light domestic fuel oil to the following specification:-

There are many fuel composition requirements that must be met when purchasing diesel fuel. The following table lists fuel properties and their limits: the more critical definitions follow.

It is very important that the fuel oil purchased for use in any engine be as clean and water-free as possible. Dirt in the fuel can clog injector outlets and ruin the finely machined precision parts in the fuel injection system. Water in the fuel will accelerate corrosion of these parts.

Fuel Oil Recommendations

Diesel fuel used for Cummins engines should be class A1 or class A2.

Sub-Base Fuel Tank

All Cummins Power Generation sets can be supplied with or without base fuel tanks. Capacities vary but are designed to provide approximately 8 hours of operation at full load. In practice with a variable load this will be extended. Recommended room layout drawings (Section B) incorporate base fuel tanks on the generators and the room height allows for this feature.

This provides a self contained installation without the addition of external fuel lines, trenches and fuel transfer pumps. Generators with base tanks are delivered fully connected and ready to run.

All base tanks have provision to accept fuel lines from externally mounted bulk fuel tanks or auxiliary free standing fuel tanks installed in the generator room.

Fuel transfer can be manually, electrically or automatically transferred via electric motor driven units.

For critical standby installations, it is recommended that a positive head of fuel is present at the engine fuel lift pump at all times.

Without Intermediate Fuel Tank (Fig. C1)

The simplest arrangement would be to supply the engine directly from the bulk storage tank and return the injector spill directly to this tank. A typical arrangement for this is shown in Fig. C1.

The principle limitations of this method are:

In order to gravity feed the engine, the outlet from the bulk storage tank must be a minimum of 600mm above the generator plinth level;

The spill return pipe to the fuel tank must be routed to avoid excessive static head on the spill return for the engine.

This is generally 165mm Hg or approximately 0.22 bar.

The supply pipework from the bulk storage tank to the engine must be sized to allow the total volume of fuel required by the engine (consumed fuel plus spill return fuel) to flow under gravity.

With Intermediate Fuel Tank (Fig. C2)

Where, due to site constraints, it is not possible to supply the engine direct from the bulk tank an intermediate tank can be located within the plant room/generator enclosure which supplies fuel directly to the engine.

This type of system can be further enhanced by the addition of the following optional items of equipment:

1. An automatic duplex fuel transfer pump and primary filter system arranged to start the standby pump should the duty pump fail. The transfer pump(s) must be sized to cater for the total fuel required by the engine, i.e. fuel consumed and the spill return volumes (Fig. C5);
2. A fusible link operated dead weight drop valve designed to cut off the supply of fuel to the intermediate tank and to transmit a signal in the event of fire;
3. A fusible link operated dump valve, arranged to dump the contents of the local tank back into the bulk tank in the event of a fire within the generator enclosure.

The connection details for these additional items of equipment are indicated. See Fig. C2.

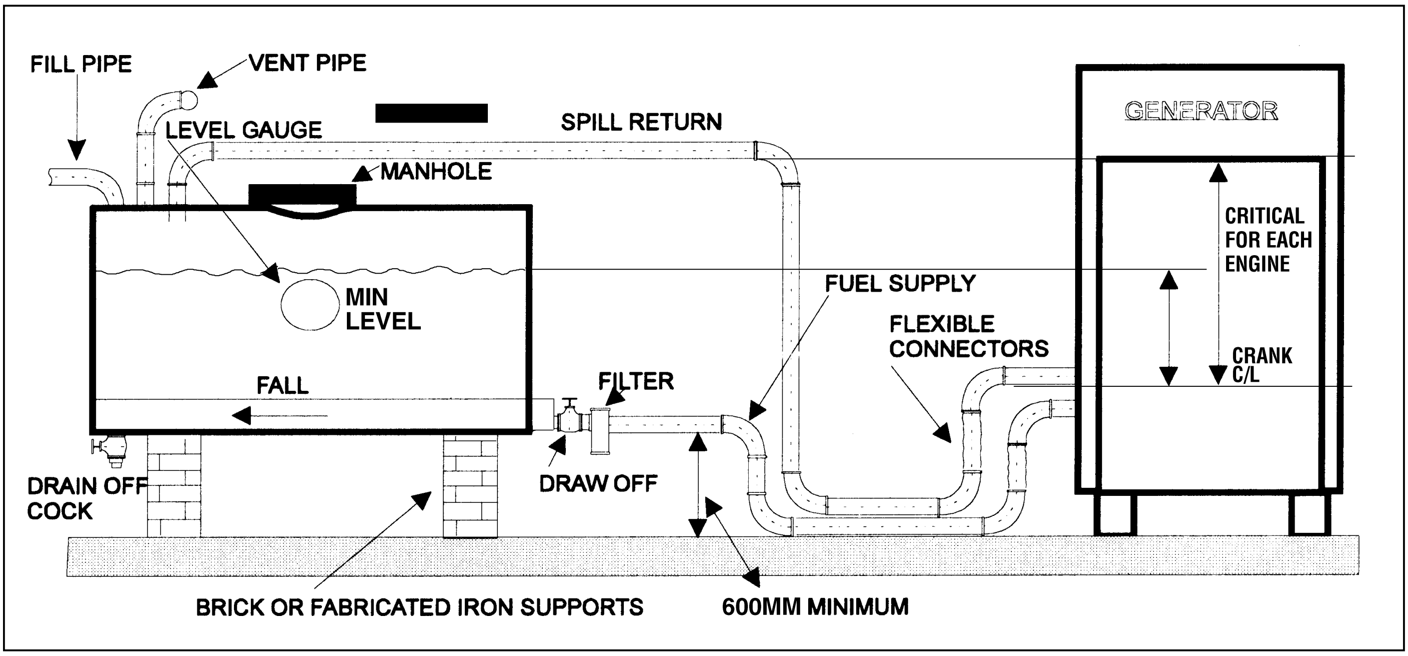


Fig. C1 Fuel System Without Intermediate Tank

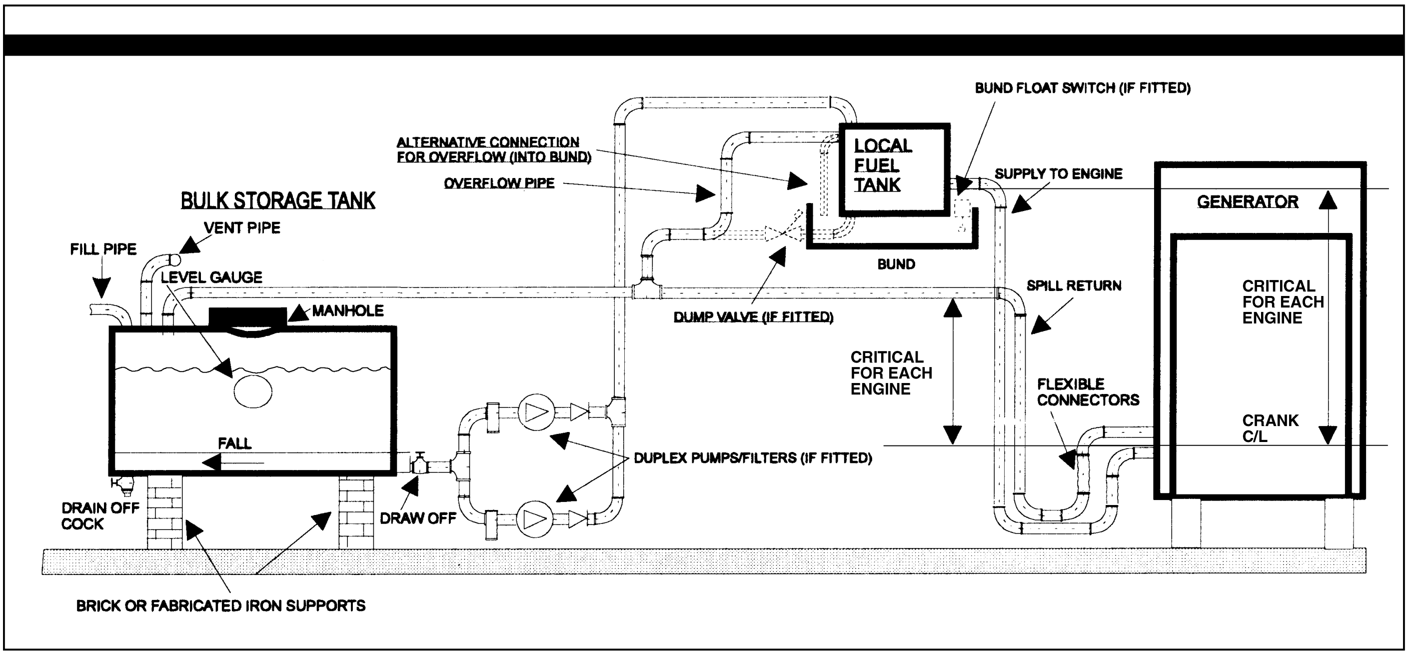
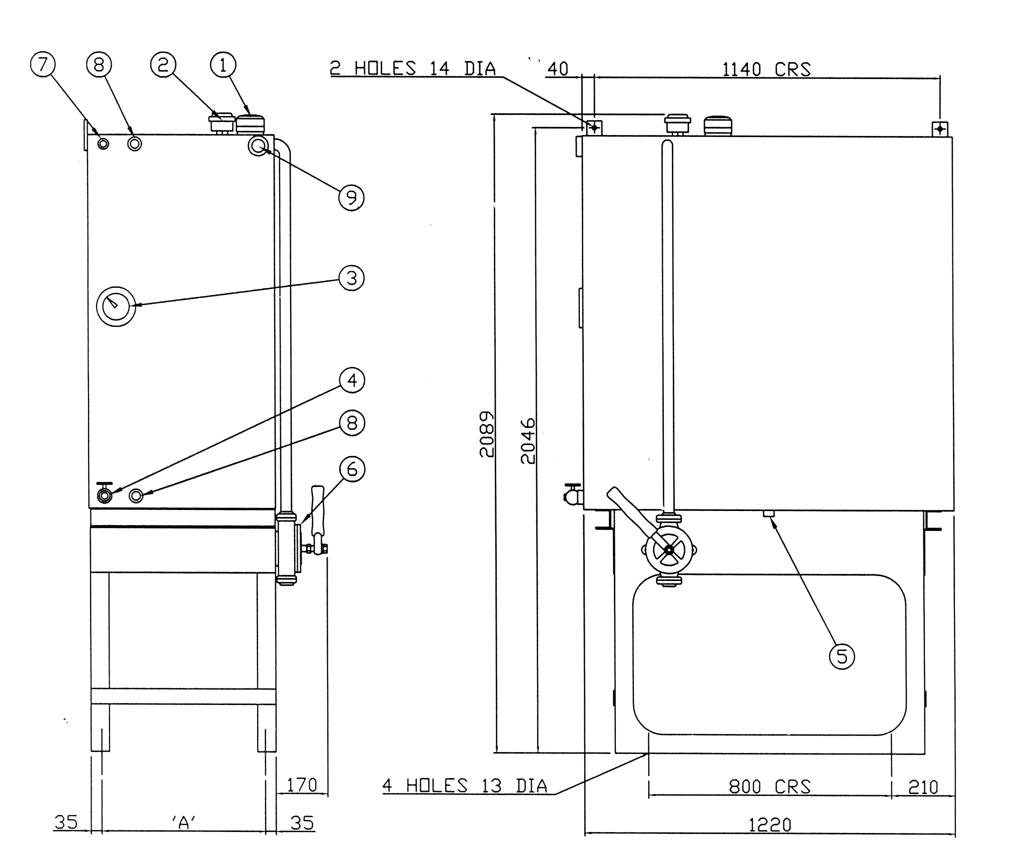


Fig. C2 Fuel System With Intermediate Tank

Example of a free standing 900 Litre fuel tank installed within a bund wall.

14000 Litre (3000 gallon) bulk fuel tank with a bund wall. Feeding a 500 kVA super silenced set with sufficient fuel for 6 days full load operation.



ITEM	DESCRIPTION	QTY
1	FILLER CAP/BREATHER	1
2	FLOAT SWITCH (OPTIONAL)	1
3	FUEL CONTENTS GAUGE	1
4	ENGINE FEED VALVE 3/4"BSP	1
5	DRAIN PLUG 1/2"BSP	1
6	HAND PUMP (OPTIONAL)	1
7	COLLAR 3/4"BSP	1
8	COLLAR 1"BSP	2
9	COLLAR 1 1/2"BSP	1

FLOAT SWITCH POSITION	FUEL CAP
HIGH LEVEL ALARM	93%
PUMP OFF	88%
PUMP ON	50%
LOW LEVEL ALARM	25%
SHUTDOWN	6%

DESCRIPTION	DIM 'A'
450 LTR. TANK C/W STAND	232
900 LTR. TANK C/W STAND	534
1350 LTR. TANK C/W STAND	836

DESCRIPTION	WEIGHT DRY
450 LTR. TANK C/W STAND	150 Kgs
900 LTR. TANK C/W STAND	190 Kgs
1350 LTR. TANK C/W STAND	235 Kgs
HAND PUMP	6 Kgs

DESCRIPTION	WEIGHT WET
450 LTR. TANK C/W STAND	600 Kgs
900 LTR. TANK C/W STAND	1090 Kgs
1350 LTR. TANK C/W STAND	1585 Kgs
HAND PUMP	6 Kgs

Fig. C3 Fuel Tank and Stand Assembly

Free Standing Fuel Tank (Fig. C3)

The capacity of a daily Service Tank can be 450 litres, 900 or 1300 litres and a transfer system arranged to automatically feed from the bulk storage tank via electric motor driven pump(s) operating from signals from a level sensing float switch. All pipework should be sized with the duty of the transfer pump and required flow rate.

Fuel tanks should **NOT** be made from galvanised iron as diesel fuel oil reacts against zinc.

The daily service tank should be positioned so that it is easily accessible for filling. In addition to an automatic filling system, provision should be made to fill from barrels by means of a semi-rotary hand pump.

A vent pipe should be extended to the highest point of the fuel system installation. The diameter of the pipe should at least match that of the fill connection. Provision should be made to prevent the ingress of dirt.

The overflow from the daily service intermediate tank can either be:

1. Piped directly back to the bulk storage tank;
2. Piped into the bund of the intermediate tank with a bund level alarm system arranged to cut off the fuel transfer pump system on detection of a spillage;
3. Piped to overflow into the bunded area, with alarm and shut off.

The feed connection on the tank should not be lower than 600mm above the level on which the engine sits in order to maintain a positive fuel head for critical applications but not more than maximum head for the fuel lift pump.

The spill return must not allow air to enter the engine fuel system when stationary.

It must not exert greater static head than permitted (see Engine Data Sheets). It must be routed away from the engine fuel feed as the fuel is hot and may require cooling if piped to small intermediate tank.

When the intermediate tank is located at a lower level than the bulk storage tank it is essential that a solenoid valve be incorporated into the transfer line.

All fuel connections to the engine should be in flexible hose to restrict vibration transmission through the pipe.

Bulk Storage Tanks

The purpose of the fuel-supply system is to store an adequate quantity of fuel to suit the application for which the system is intended. The bulk storage tanks should be sized accordingly.

The filling of the tanks will be by means of a fill connection housed in a suitable lockable cabinet located so as to permit easy access by delivery tanker. This cabinet may also house a contents gauge and an overfill alarm connected to the float switch inserted into a manhole on the tank.

Bulk Storage Tanks

When used with an intermediate tank an electrically driven fuel transfer pump will be needed. Where possible this pump should be located close to the bulk tank on the grounds that any given size of pump has a greater ability to push fuel than to pull it. It is good practice to install a relief valve to return excess fuel from the discharge to the suction side of the pump.

The storage tank should incorporate the following facilities:

- provision for isolation during cleaning or repair (where multiple tanks are installed);
- a fill connection;
- a vent pipe/breather;
- intermediate tank overflow connection;
- inspection or manhole cover of approx. 18ins. diameter;
- a sludge drain connection at the lowest point;
- a level indicator (if contents are transmitted to the fill point cabinet); or dipstick
- a feed connection at the opposite end to the sludge drain connection;
- strainer and (where necessary) a foot valve.

The tank piers or supports should be arranged so that the tank is tilted approx 5° from the horizontal. These supports should be constructed or protected so as to have a standard fire protection of 4 hours and should permit thermal movement. That end of the tank to which the principle pipelines are to be connected should be secured to its supports, the other end should be free to move.

A purpose built bund should be provided for all above ground tanks, constructed in consideration of the following requirements:

- It should be large enough and be structurally sound enough to hold at least 10% more than the contents of the tank;
- The floor should be laid to fall to an impervious un-drained sump
- Walls and floor should be lined with an impervious lining;
- All round access to tank's sides and fittings should be possible;
- A hand or electric pumping system should facilitate the draining of the bund.
- Metalwork should be earthed in accordance with local regulations.

For underground tanks the size of the excavation should be large enough to permit a clear gap of at least 1m between the shell of the tank and the walls before backfilling. Underground tanks should be fitted with an extended nozzle of sufficient length to bring the manhole clear of the backfill which should be some 0.6m above the top of the tank.

Determining Pipe Sizes

Minimum pipe sizes are determined by the size of the inlet to the fuel transfer pump. The pipe inner diameter must be a least as large as the transfer pump inlet. If the piping must carry the fuel over long distances, the pipe size must be increased. An auxiliary transfer pump at the tank outlet may also be needed to avoid high suction pressure within the piping. In all cases, excessive fuel line suction pressures must be avoided. At high suction pressures the fuel will vaporise in the piping and the fuel supply to the engine will be decreased.

When selecting pipe for fuel system installation, the cloud points and pour points of the diesel fuel must be considered. Over normal temperature ranges, this will not be a factor. However, as the fuel cloud and pour point temperatures are approached, the oil will become thicker and the pipe size will have to be increased.

When sizing piping, always remember to account for pressure drop across filters, fittings and restriction valves.

A flexible connector must be added to isolate the engine vibration from the fuel piping. If this vibration is not isolated, the piping could rupture and leak. The flexible connector must be as close to the engine transfer pumps as possible.

All piping must be properly supported to prevent piping ruptures. Use pipe hangers to isolate vibration from the system.

Exposed fuel piping must never run near heating pipes, furnaces, electrical wiring or exhaust manifolds. It the area around the piping is warm, the fuel lines should be insulated to prevent the fuel and piping from picking up any excess heat.

All pipes should be inspected for leaks and general condition, including cleanliness before installation. Back flush all lines to the tank before start-up to avoid pulling excess dirt into the engine and fuel piping system. After installation, the air should be bled from the fuel system. A petcock should included at some high point in the system to allow air removal.

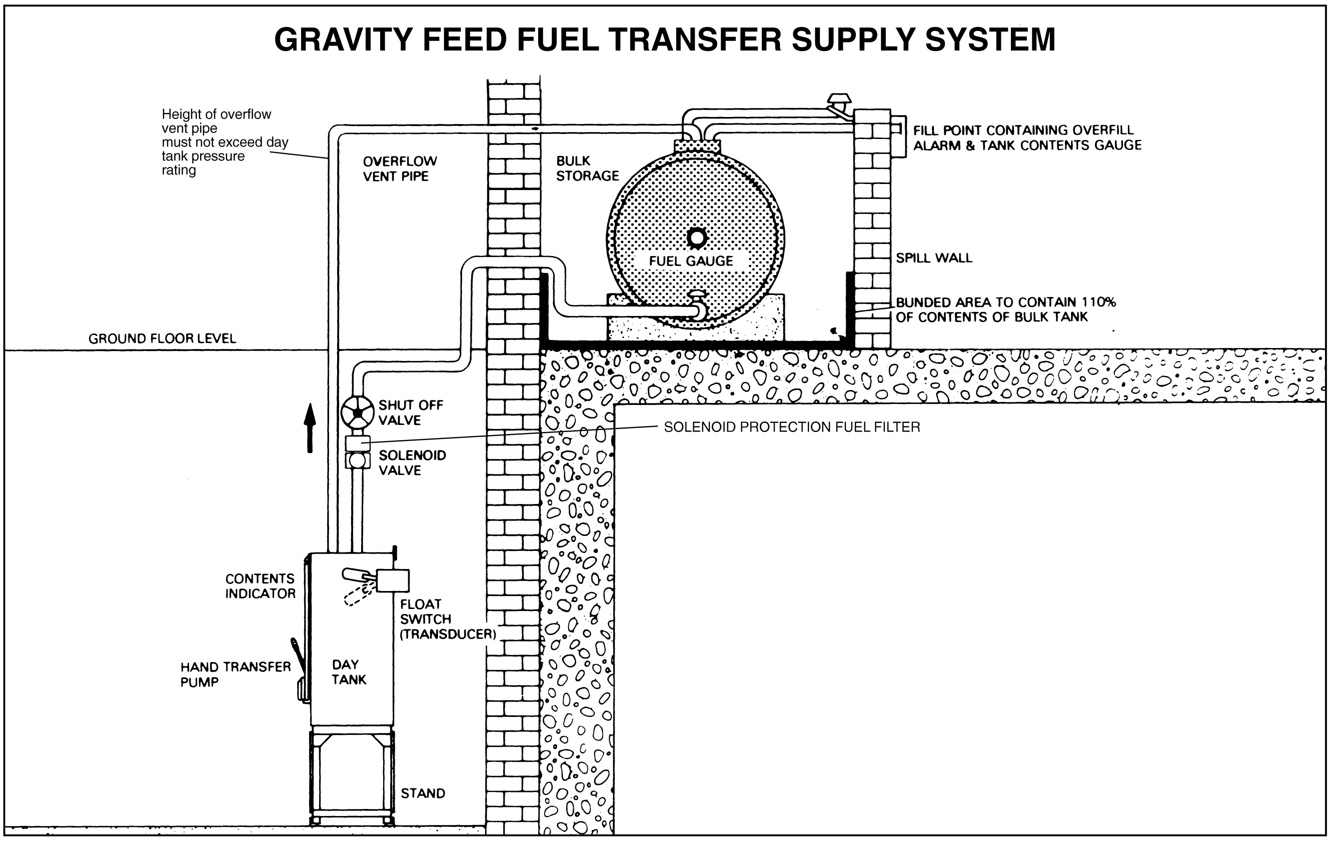

GRAVITY FEED FUEL TRANSFER SUPPLY SYSTEM
Height of overflow vent pipe must not exceed day tank pressure rating
OVERFLOW VENT PIPE
BULK STORAGE
FILL POINT CONTAINING OVERFILL ALARM & TANK CONTENTS GAUGE
FUEL GAUGE
SPILL WALL
BUNDED AREA TO CONTAIN 110% OF CONTENTS OF BULK TANK
GROUND FLOOR LEVEL
SHUT OFF VALVE
SOLENOID PROTECTION FUEL FILTER
SOLENOID VALVE
CONTENTS INDICATOR
FLOAT SWITCH (TRANSDUCER)
HAND TRANSFER PUMP
DAY TANK
STAND

Fig. C4

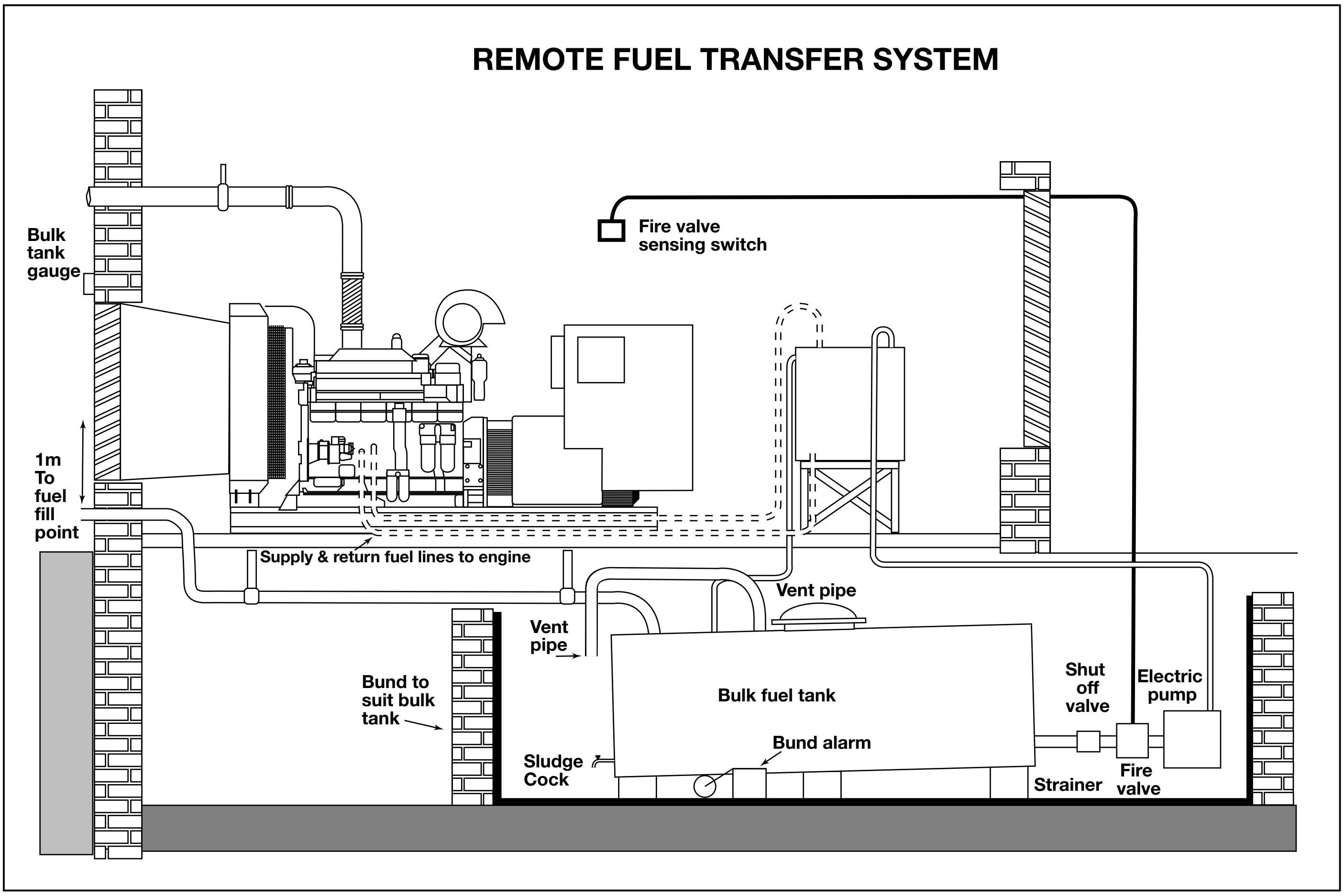

REMOTE FUEL TRANSFER SYSTEM
Fire valve sensing switch
Bulk tank gauge
1m To fuel fill point
Supply & return fuel lines to engine
Vent pipe
Vent pipe
Bund to suit bulk tank
Bulk fuel tank
Shut off valve
Electric pump
Bund alarm
Sludge Cock
Strainer
Fire valve

Fig. C5

Use plugged tees, not elbows, to make piping bends. This will allow for cleaning by removing the plugs and flushing out the lines. All threaded pipe fittings must be sealed with a suitable paste.

Caution: Do not use tape to seal fuel line pipe fittings. Pieces of tape could shear off and jam in the pump or injectors.

Fuel Return Lines

Fuel return lines take the hot excess fuel not used in the engine cycle away from the injectors and back to either the fuel storage tank or the day tank. The heat from the excess fuel is dissipated in the tank.

Caution: Never run a fuel return line directly back to the engine fuel supply lines. The fuel will overheat and break down.

The fuel return lines should always enter the storage or day tank above the highest fuel level expected. This statement is true for all Cummins Gensets powered by engines with the PT fuel system (L10, NT, V28 and K range). However with sets using the B series, C series or the QST30 series engines drain lines for fuel will cause siphoning back through the supply line and result in hard starting if installed above the fuel level.

The fuel return line should never be less than one pipe size smaller than the fuel supply line.

Fuel Coolers

Fuel returned to the fuel tank normally collects heat from the engine. In some cases, specifically using QSK45 and QSK60 engined gensets, a fuel cooler should be installed within the fuel system.

TYPICAL DIMENSIONS OF BULK FUEL STORAGE TANKS (CYLINDRICAL TYPE)

	DIA.	LENGTH
500 GALLONS 2273 LITRES	1372mm 4ft 6ins	1753mm 5ft 9ins
1000 GALLONS 4546 LITRES	1372mm 4ft 6ins	3353mm 11ft 0ins
2000 GALLONS 9092 LITRES	1981mm 6ft 6ins	3277mm 10ft 9ins
3000 GALLONS 13638 LITRES	2134mm 7ft 0ins	4115mm 13ft 6ins
4000 GALLONS 18184 LITRES	2438mm 8ft 0ins	4267mm 14ft 0ins
5000 GALLONS 22730 LITRES	2286mm 7ft 6ins	5944mm 19ft 6ins
6000 GALLONS 27276 LITRES	2744mm 9ft 0ins	5029mm 16ft 6ins

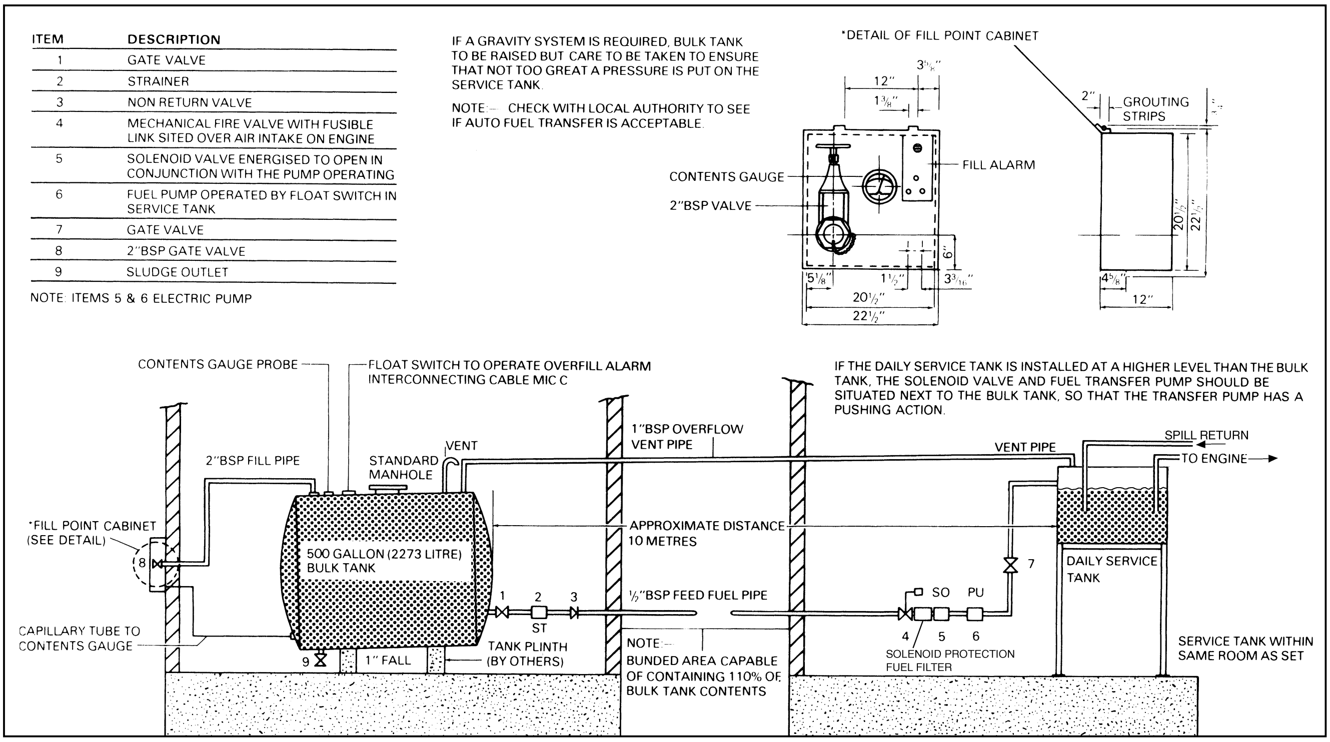


Fig. C6 Suggested Installation for Bulk and Set Tanks

Exhaust System

Sizing

An exhaust system should be designed to dispel the exhaust gases to atmosphere at the nearest convenient point in an installation. The length of the run and the number of changes in direction should be kept to a minimum to avoid exceeding optimum.

The calculation of the effect on the back pressure is based upon the restriction through the straight lengths of pipe, the bends and the silencers. The smaller the bore of the pipe, the greater its length and the more times it changes its direction, the greater is its resistance to flow. The resistance through the silencer varies according to the level of attenuation it is to achieve.

The formula for this calculation is based upon the following parameters:

F = Exhaust gas flow (Fig. C8)
P = Maximum allowable back pressure
A = Cross sectional area of the pipe
L = Length of straight pipe
B = Number of bends
R = Resistance through the silencer(s)
V = Linear velocity through the silencer

Listed below are pipe nominal bores and their cross sectional areas (A):

Cross Sectional Area of Exhaust Piping			
Inches	sq. ft^2	mm	sq. m^2
3	0.049	76	0.0045
4	0.087	102	0.008
6	0.196	152	0.018
8	0.349	203	0.032
10	0.545	254	0.050
12	0.785	305	0.073
14	1.070	356	0.099
16	1.396	406	0.129

Engine	Silencer Exhaust Bore	
	inches	mm
B3.3, 4B, 6B	3	76
6C	4	100
L, N, K19, V28	6	152
K38, QSK30	6x2	152
K50, QSX15	8	200
QSK60	12	300

The back pressure limit for most Cummins engines is 3 ins Hg (76mm Hg) although gensets using the latest designs are down to 2 ins Hg (50mm Hg) based on the maximum exhaust flow stated. If in doubt refer to the technical data sheets, Section G.

The example given in Fig. C8, shows a typical exhaust run complete with bends, straight lengths and silencer details. The pressure loss in each part of the system is dependent upon the average velocity (V) through it. Add together the pressure loss for each part of the system. **Take an estimate of the size of the pipe by starting with the bore of the exhaust flange off the manifold and increasing the size by 25mm (1") for each 6m (20ft) length or 3 x 90° bends.**

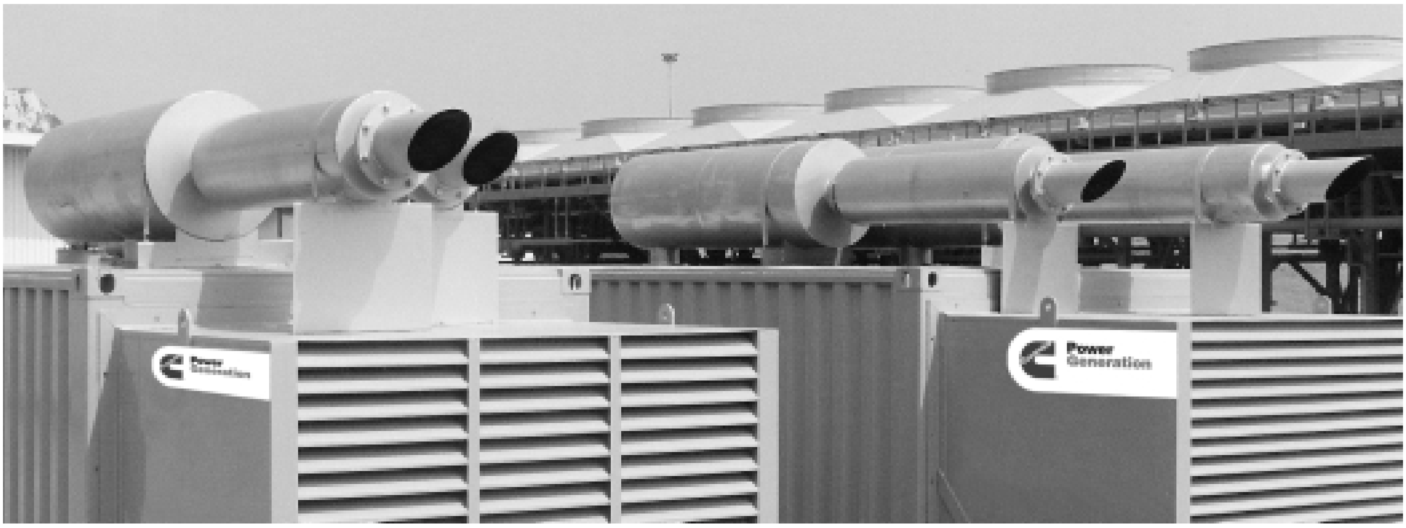
Select the silencers required to achieve the noise attenuation required and determine the linear velocity through each one by dividing the flow (F) in ft/sec by the cross sectional area (A) of the bore of the silencer.

eg: L range engines (250 kVA) silencer bore = 6" (152mm) equal to 0.196 sq.ft

Exhaust Gas Flow @ 1500 rpm prime = 1405 cubic ft/min.

$\frac{1405\ \text{CFM}}{0.196\ \text{ft}^2}$ = 7168 ft/min ÷ 60 = 119 ft/second.

Bore Velocity. Using 119 against the graph Fig. C10 we read off 4 inches Wg (100mm Wg) for silencer resistance.



The combination of residential and a standard silencer as the tail pipe will effectively reduce exhaust noise.

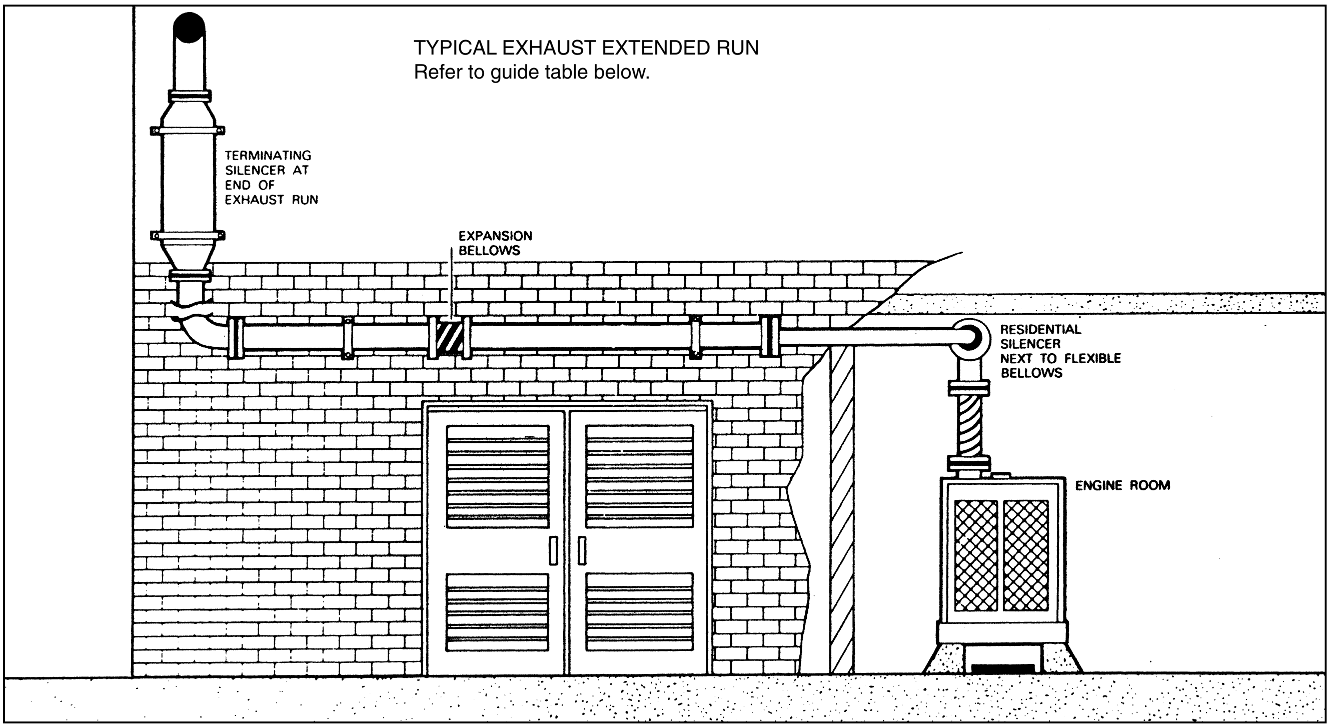


Fig. C8 Typical Exhaust Run

Fig. C7 Exhaust pipeline recommendations

Exhaust outlet size mm (inches)		Pipe size recommendations* Up to 6m (20ft)		6m to 12m (20 to 40ft)		12m to 18m (40 to 60ft)		18m to 24m (60 to 80ft)	
mm	(ins)	mm	(ins)	mm	(ins)	mm	(ins)	mm	(ins)
50	(2)	50	(2)	63	(2½)	76	(3)	76	(3)
76	(3)	76	(3)	89	(3½)	100	(4)	100	(4)
89	(3½)	89	(3½)	100	(4)	100	(4)	100	(4)
100	(4)	100	(4)	127	(5)	127	(5)	150	(6)
127	(5)	127	(5)	150	(6)	150	(6)	200	(8)
150	(6)	150	(6)	150	(6)	200	(8)	200	(8)
200	(8)	200	(8)	200	(8)	254	(10)	254	(10)
254	(10)	254	(10)	254	(10)	305	(12)	305	(12)
300	(12)	300	(12)	355	(14)	400	(16)	460	(18)

* Note. These sizes are for guidance only. Specification and special silencer applications may affect the actual line sizes.

The following formula can be used to calculate the actual back pressure to the exhaust system for a given length and diameter.

$$P = \frac{L \times S \times Q^2}{5184 \times D^5}$$

L = Pipe length and elbows in feet/metres
Q = Exhaust flow CFM/m³/sec
D = Inside diameter of pipe inches/metres
S = Specific weight of exhaust gas lb./cu.ft./kg/m³
S will vary with the absolute temperature of exhaust gas as follows

$$S = \frac{41}{460 + \text{exhaust temp. °F}} \quad \Big| \quad S = \frac{365}{273 + \text{exhaust temp. °C}}$$

P = Back pressure (p.s.i.). Must not exceed max. allowable back pressure as shown in accompanying table.

Some useful conversions

Millimeters to inches – multiply by 0.03937
Inches to centimetres – multiply by 2.54
Metres to feet – multiply by 3.281
Cubic metres to cubic feet – multiply by 35.31
Centigrade to Fahrenheit – multiply by (C x 1.8) + 32
p.s.i. to inches of water (H2O) – divide by 0.0361
Inches of water to mm of water – multiply by 25.4
Metric formula

$$P = \frac{L \times S \times Q^2}{77319 \times D^5}$$

Note: Above KTA19G all engines have twin exhaust manifolds which may either be ducted into one exhaust run or used as two separate runs.

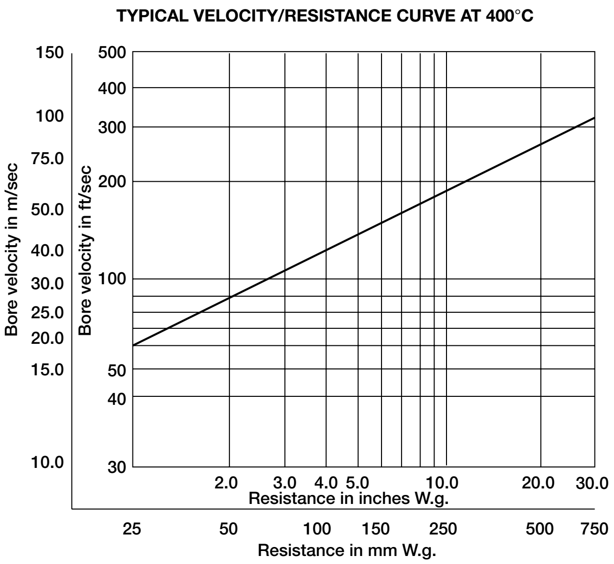
Fig. C9 Exhaust Gas Flows and Temperatures

Engine	1500 rpm				1800 rpm			
	Prime		Standby		Prime		Standby	
	CFM	°F	CFM	°F	CFM	°F	CFM	°F
B3.3G1	282	842	302	926	225	815	250	860
B3.3G2	282	887	302	975	332	905	357	950
4B3.9G*	260	1105	280	1215	325	1120	350	1270
4BT3.9G1	290	870	315	935	370	860	395	915
4BT3.9G2	335	970	365	1030	420	950	460	1010
4BTA3.9G1	377	940	352	890	420	950	460	1010
6BT5.9G2	600	1070	650	1130	745	1010	800	1060
6CT8.3G2	895	970	980	1040	1100	951	1221	1065
6CTA8.3G2	1090	1180	1205	1210	1380	1095	1515	1130
6CTAA8.3G1	1080	1080	1272	1100	1436	925	1605	952
LTA10G2	1405	955	1290	935	1655	905	1915	920
LTA10G3	1371	950	1508	975	1644	939	1904	959
NT855G6	2270	1065	2450	1125	2290	950	2400	975
NTA855G4	2390	975	2595	1005	1866	895	2030	925
QSX15G8	2800	855	3090	880	3105	885	3625	925
KTA19G3	2850	975	3155	990	3345	880	3630	915
KTA19G4	3039	1000	3398	1604	3673	898	3945	939
VTA28G5	4210	920	4340	945	4635	885	5040	935
QST30G1	1995	527	2170	538	2620	455	2908	480
QST30G2	2216	538	2526	557	2794	467	3118	496
QST30G3	2430	541	2720	563	3000	464	3290	481
QST30G4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
KTA50G3	7900	968	8500	977	8400	860	9100	887
KTA50G8	8150	900	9210	950	–	–	–	–
KTA50G9	–	–	–	–	9600	880	10650	960
QSK60G3	10700	940	11800	960	–	–	–	–
QSK60G4	10990	805	11880	842	–	–	–	–
QSK60G6	–	–	–	–	14070	860	15500	890

CFM = Cubic feet per minute
See Section G Data Sheets for metric

Based on 40°C ambient conditions.

Fig. C10



Resistance at temperature T°C: $RT = \frac{R400 \times 673}{T + 273}$

where R400 = resistance at 400°C from graph

Pressure drop calculations

Section A - Straight length of pipe.

Section B - 90° bends

Section C - Straight length of pipe, one sixth that of Section A.

Section D - The exhaust gas silencer, the manufacturers data is required to calculate the pressure drop.

Section E - Straight length of pipe, one third that of Section A

Section F - Outlet, total pressure drop of the exhaust system

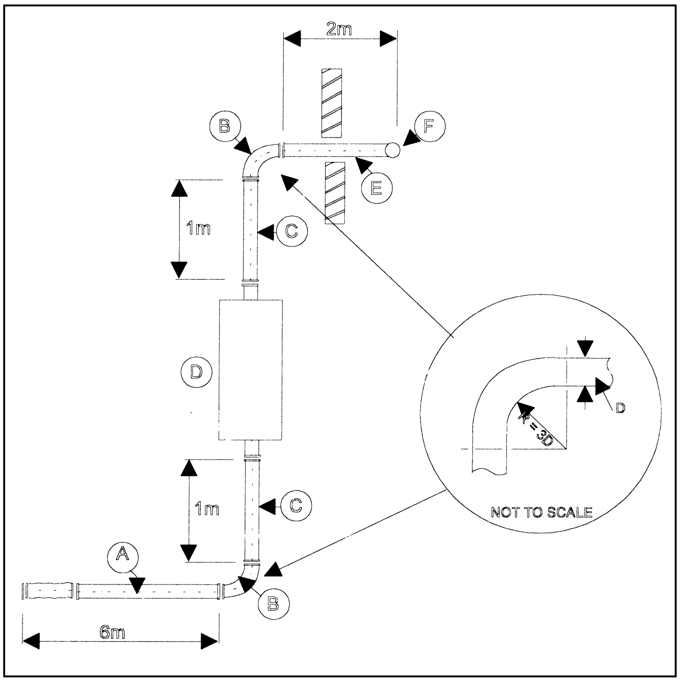


Fig. C11 Typical Exhaust Run Complete with Bends

Select the appropriate silencer(s) required to achieve the noise attenuation required and determine the linear velocity through each one by dividing the flow (F) in ft/sec by the cross sectional area of the bore of the silencer.(A)

e.g. F(8500cfm) = 64.98ft/sec   60 x A(2.180 Ft²)

The resistance through the silencer can be determined by reference to the silencer manufacturer's nomograph. (Nelson Burgess BSA range nomograph is shown as Fig. C12). In the event that a reactive and an absorptive silencer is needed to achieve the noise attenuation level, the absorptive silencer would be placed after the reactive one and its resistance should be considered the same as an equivalent bore straight length of pipe.

When added to the resistance through the silencer(s) the total should not exceed the maximum allowable back pressure of the engine. If it does, the procedure should be repeated using an increased bore pipe and/or silencer(s).

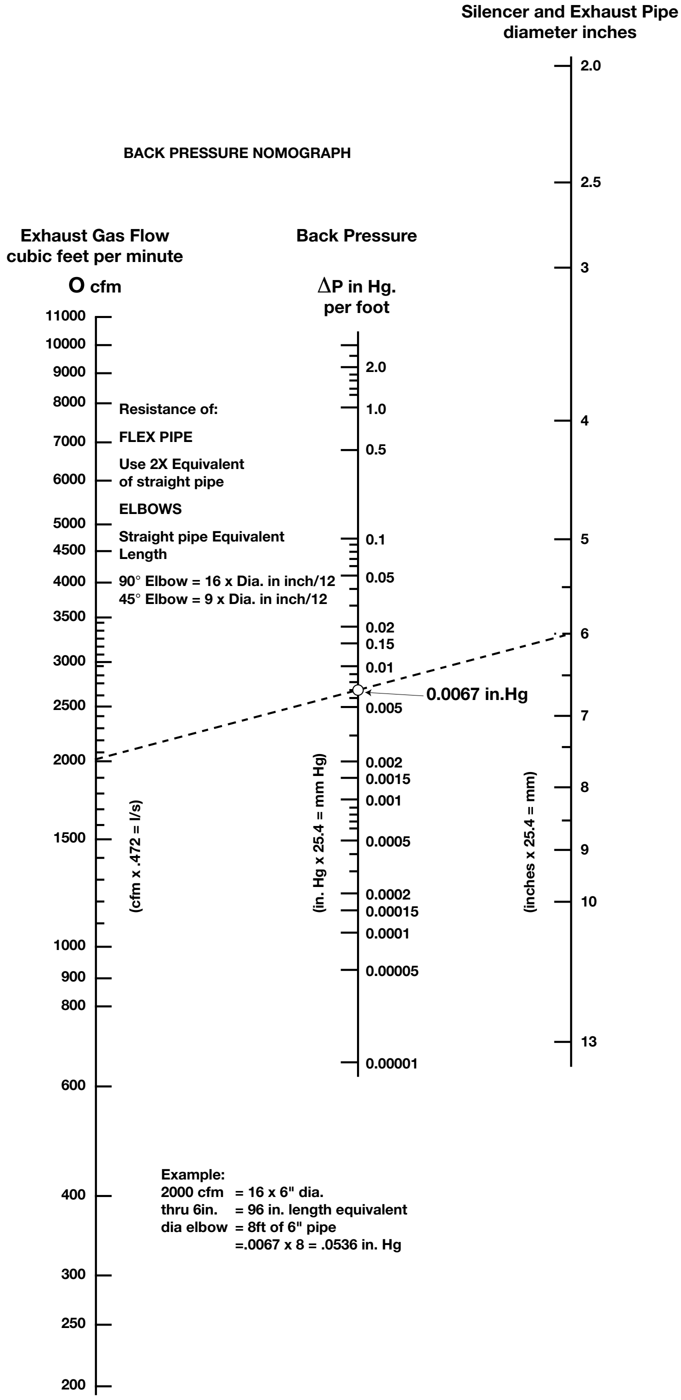


Fig. C12 Silencer and Straight Line Nomograph

Routing

Once the final size and route of the pipework and the silencer have been established, the exhaust route can be determined, taking into account the following factors:

A flexible bellows unit must be fitted on the engine connection to allow the engine to move on its mountings;

If the silencer is to be located within the plant room, due to its physical size and weight it may need to be supported from the floor;

It may be necessary to install expansion joints at each change of direction to compensate for the thermal growth in the pipe during operation;

The inner radius of a 90° bend should be 3 times the diameter of the pipe;

The primary silencer should be mounted as close as possible to the engine;

When installing a long exhaust system, it may be necessary to install a terminal silencer to reduce any regenerated noise that may occur in the pipework after the primary silencer.

The termination point should not be directed at combustible materials/structures, into hazardous atmospheres containing flammable vapours, where there is a danger that the gases will re-enter the plant room through the inlet air vent, or into any opening to other buildings in the locality.

All rigid pipework should be installed in such a manner that the engine's exhaust outlet is not stressed. Pipes should be routed so that they are supported by fixtures to the building fabric or by existing structural steelwork where such methods are acceptable;

Installation

Due to its overall size and weight, if the silencer is to be located within the plant room consideration should be given during the initial planning stages of the installation as to the exact method of moving this item into the room and then lifting it into final position as it may be necessary for it to be installed before the generator set is moved into position.

To ensure that condensation does not run back into the exhaust manifold, horizontal pipes should slope downwards away from the engine. Provision should be made for extending the condensate drain on the silencer and any other drain points, such as those at the base of vertical pipework, to a readily accessible position for regular draining to take place.

Where the pipe passes through combustible roofs, walls or partitions it should be protected by the use of metal sleeves with closing plates infilled with mineral wool. (See Fig. C13).

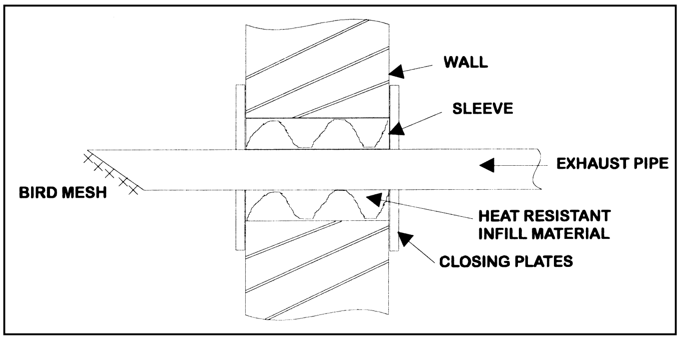


Fig. C13 Protection by the Use of Metal Sleeves

Where possible, in order to reduce the heat gain into the plant room, as much of the exhaust system as possible should be located outside of the plant room, with the remaining pipework within the room being fully lagged and clad. However, if due to the specific site constraints it is necessary to install the silencer and additional pipework within the room it should be fully insulated with 50mm of mineral wool and clad with aluminium foil. It may also be necessary to install the silencer inside the plant room to avoid noise break-out from the pipe connecting to the engine side of the silencer.

Care should be taken when insulating at pipe support or guide points so that the thermal growth of the pipe can take place. (See Fig. C14).

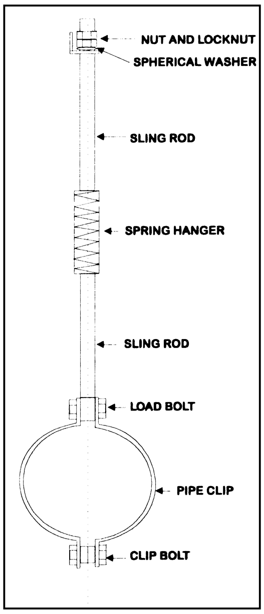


Fig. C14 Allowing for Thermal Growth

At the termination point the pipe should be protected against the ingress of rain either by turning into the horizontal plane with a mitred end or by being fitted with a rain cap.

Exhaust System Design Considerations and Requirements

Noise Level

The exhaust noise created by the engine must be attenuated sufficiently to satisfy all local regulations and on-site requirements. This can be accomplished with proper silencer selection.

– Industrial (or Non-Critical)	12 to 18 dBA attenuation
– Residential	18 to 25 dBA attenuation
– Critical	25 to 35 dBA attenuation

System Restriction

It is important to keep the exhaust back pressure as low as possible. Excessive exhaust back pressure can contribute to poor engine performance and poor durability by negatively affecting combustion efficiency and increasing gas temperatures.

The back pressure limit on many Cummins generator drive engines is normally 3 in Hg (76mm Hg) but can be down to 2 in Hg (50mm Hg) on the latest engines based on the maximum exhaust gas flow stated on the Engine Data Sheet. To satisfy this requirement, it is important to minimize piping length, elbow quantities, and silencer restriction, and to maximize piping diameters.

Exhaust Outlet Location

Location Planning

Normally, the discussion for the exhaust outlet location would be included within a discussion of piping design. However, the exhaust outlet location is worthy of a dedicated discussion.

The most convenient exhaust outlet location is not always the best location. The designer must recognize that prevailing winds, building design, property layout, the distance to the property line, and the available exhaust gas velocity are each critical ingredients in selecting the proper outlet location. The gases must not have the opportunity to enter any vital air inlets (windows, doors, ventilation ducts, engine combustion air intakes, engine cooling/ventilation intakes, etc.), and many items must be considered to prevent this.

Every precaution must be taken when selecting the proper exhaust outlet location to prevent exhaust gases from contaminating the air entering vital air inlets. Such vita air inlets include windows, building ventilation systems, engine combustion air intakes, doors, and engine cooling/ventilation intakes.

Special consideration must be given to prevailing winds, and potential stagnant air pockets near buildings. These are as important as the mere distance between the exhaust outlet and the vital air inlets.

The exhaust outlet must be located so as to minimize the effects of stack noise on workers and neighbours and to minimize the potential of carbon particle accumulation on nearby structures and to minimize the effects of noise.

Piping Design

All exhaust piping must be well supported by the building or enclosure.

The silencer must never be mounted directly to the exhaust manifold or turbocharger outlet on any engine without supplementary support.

The exhaust outlet must be fitted with a rain cap, bonnet, or otherwise be designed to prevent rainwater and snow from entering the exhaust system.

A condensate trap and drain valve must be fitted as close as practical to the engine to collect any water vapour that might condense from the exhaust gas.

System Costs

Exhaust systems certainly cost money, but shaving costs on the front end of a project may well cost the end-user a great deal over the life of the unit. A restrictive system will force the engine to run at an unacceptable air to fuel ratio and could lead to temperature related durability problems and smoke complaints.

System Length

The designer must make every effort to find the shortest practical exhaust piping route between the engine and the properly selected exhaust outlet location. The following list summarises some of the reasons why the system should be as short as possible:

– Minimize system restriction (back pressure).

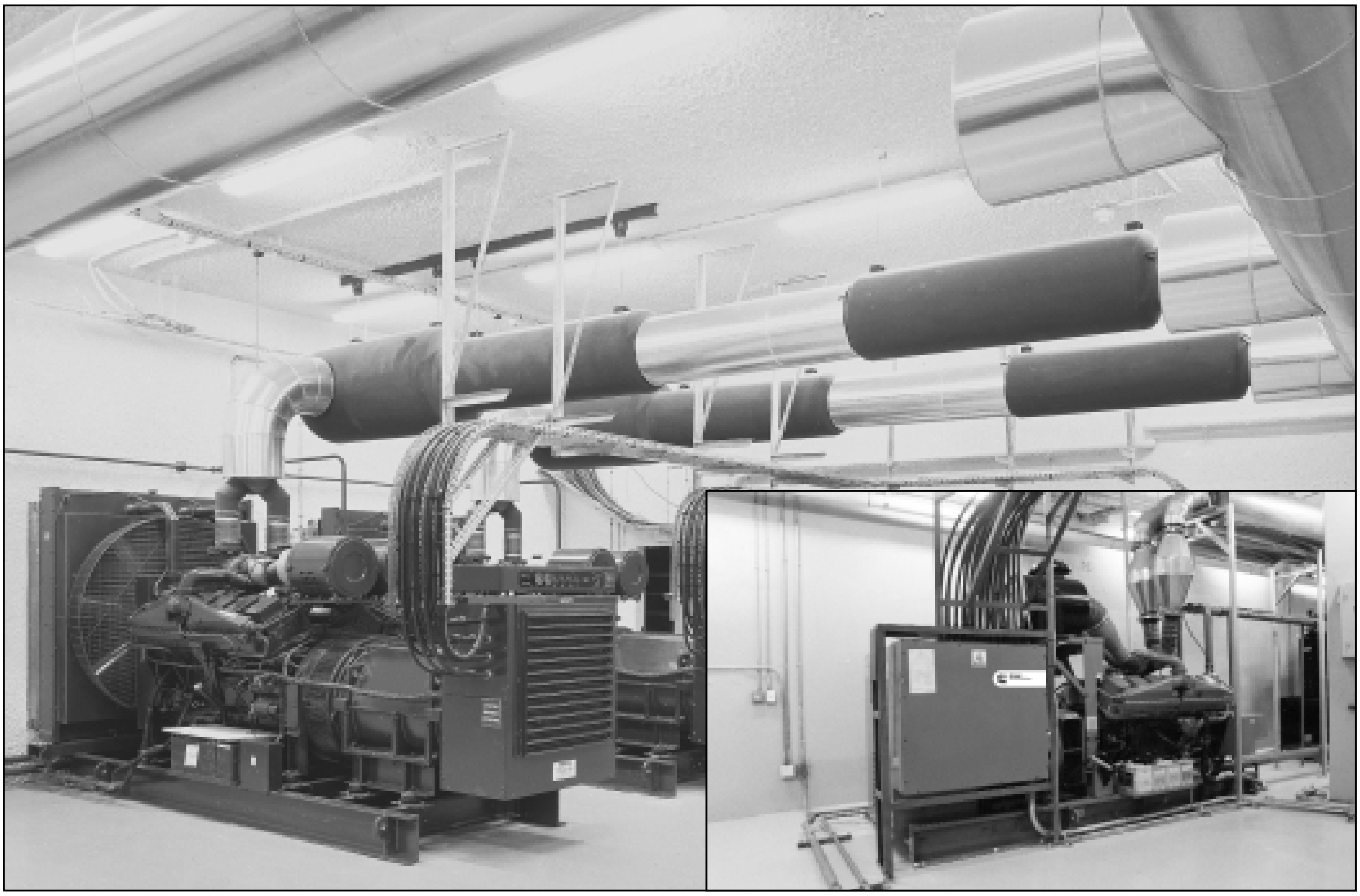
– Maintain reasonable exhaust gas exit velocities so that gases are easily dispersed.

– Minimize exhaust gas condensing so that gases are not excessively dense when they exit.

Dense gases exiting at a low velocity contribute to smoke complaints and to poor dispersion.

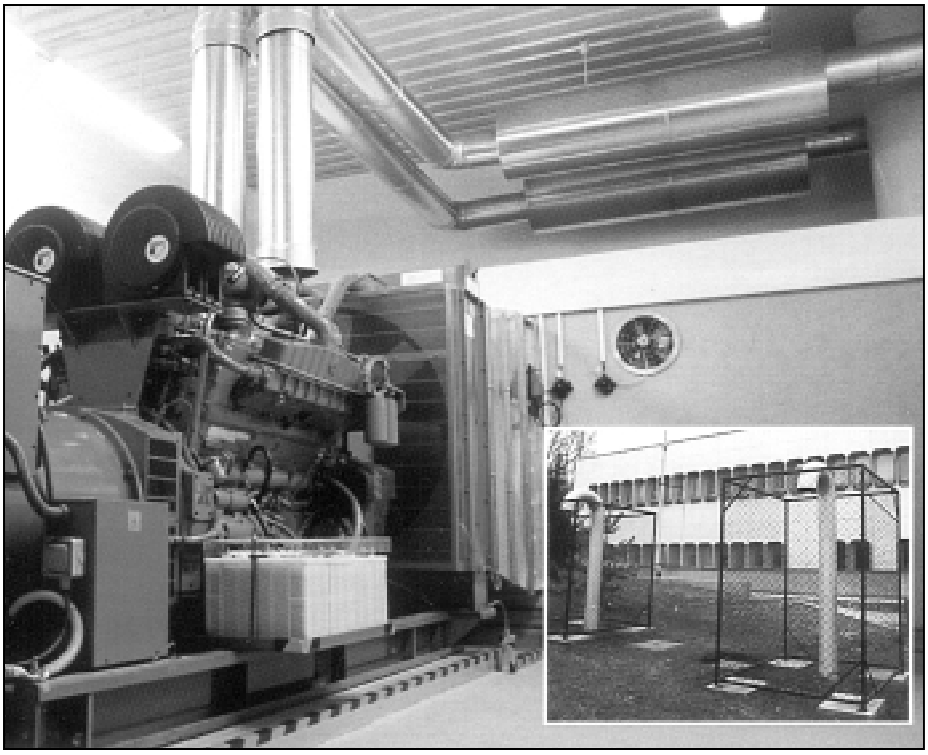
Flexible Connections

The piping system will expand and contract as it heats and cools. It will also be susceptible to the vibration and motion of the engine. For these reasons, a flexible piping connection must be placed between the engine and the piping system. The flexible pipe will minimize the stresses on the engine and the stresses in the piping system. The flexible pipe should be located at or near the engine exhaust outlet (turbo or exhaust manifold).



Good example of clean and well lagged exhaust installation run from two 725 kVA twelve cylinder engined powered standby sets.

Example of set with catalytic converters to reduce exhaust emissions.



Dual exhaust run, lagged and aluminium foil clad from a Cummins VTA28 twelve cylinder twin turbocharged engine. Set output 640 kVA/50 Hz.

Mandatory Accessories

The exhaust outlet must be fitted with a rain cap, bonnet or otherwise be designed to prevent rainwater and snow from entering the exhaust system. Flapper-type rain caps are effective devices, but they are subject to the effects of corrosion and carbon buildup which can prevent them from operating properly. It is wise to use these only in applications where they can be easily accessed for maintenance.

A condensate trap and drain valve must also be fitted as close as practical to the engine to collect any water vapour that might condense from the exhaust gas. Such a device is recommended, but rarely practical for a portable unit.

Common Systems for Multiple Exhaust Sources

The practice of manifolding or plumbing engines into a common exhaust system with furnaces, boilers, or other engines is not recommended. Non-running engines are at great risk to suffer damage due to the buildup of carbon and condensation from a running engine or other exhaust source. The turbocharger on a non-running engine can be driven by the exhaust flow from other sources and result in turbocharger bearing damage due to lack of lubrication.

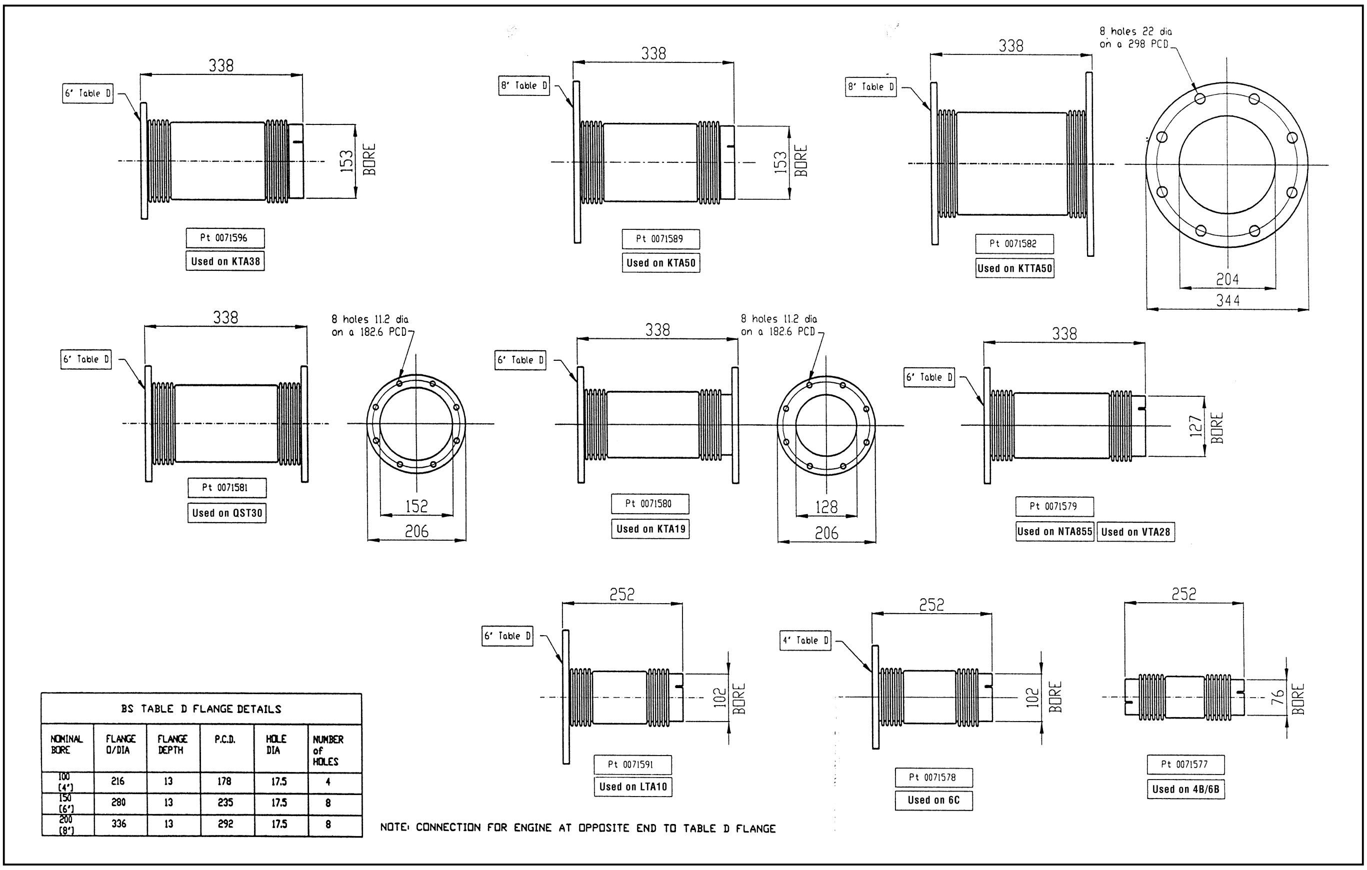
There is no effective way to safely isolate engines from a common piping system. Valves used in the piping to isolate specific branches tend to suffer from carbon buildup and eventually leak or become stuck.

The exhaust gas velocities also tend to suffer in a system like this especially when only a few exhaust sources are operating. The exhaust gases condense and do not disperse well at the outlet. It may be possible to develop a forced air system to push the gases through the common stack to achieve the desired velocity, but this adds complication to the system. Cummins has no experience with such a forced air/blower system.

Catalytic Converters

Where emissions must be kept to an absolute minimum, catalytic converters may be fitted. This is a combination of sold element filters and chemical reactions to reduce unwanted gases.

Three 1 MW standby sets powered by KTA38G4 engines installed in a hospital with catalytic converters to reduce exhaust emissions.

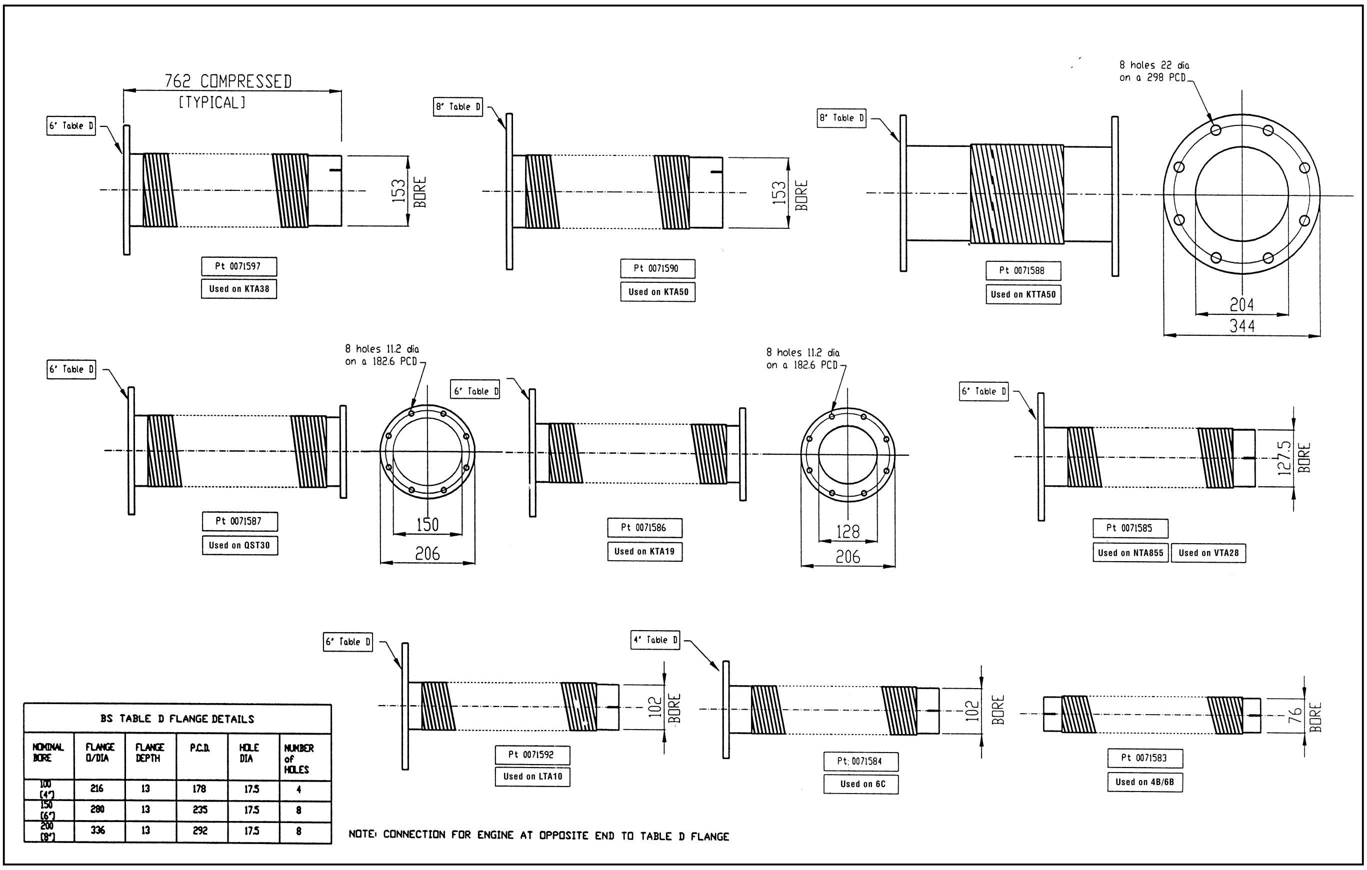


BS TABLE D FLANGE DETAILS

NOMINAL BORE	FLANGE O/DIA	FLANGE DEPTH	P.C.D.	HOLE DIA	NUMBER of HOLES
100 (4")	216	13	178	17.5	4
150 (6")	280	13	235	17.5	8
200 (8")	336	13	292	17.5	8

NOTE: CONNECTION FOR ENGINE AT OPPOSITE END TO TABLE D FLANGE

Standard Exhaust Bellows



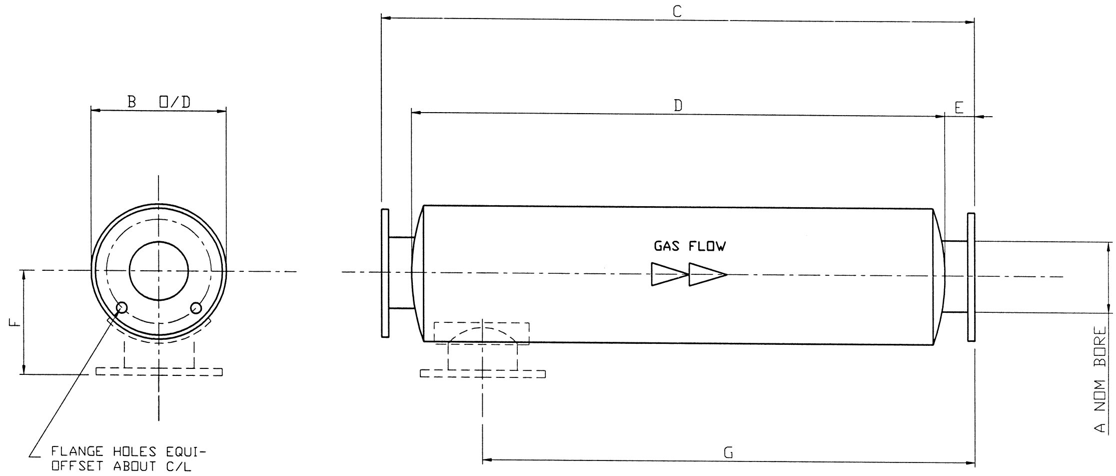
BS TABLE D FLANGE DETAILS

NOMINAL BORE	FLANGE O/DIA	FLANGE DEPTH	P.C.D.	HOLE DIA	NUMBER of HOLES
100 (4")	216	13	178	17.5	4
150 (6")	280	13	235	17.5	8
200 (8")	336	13	292	17.5	8

NOTE: CONNECTION FOR ENGINE AT OPPOSITE END TO TABLE D FLANGE

Standard Exhaust Flex

GA of Exhaust Silencers (Industrial)

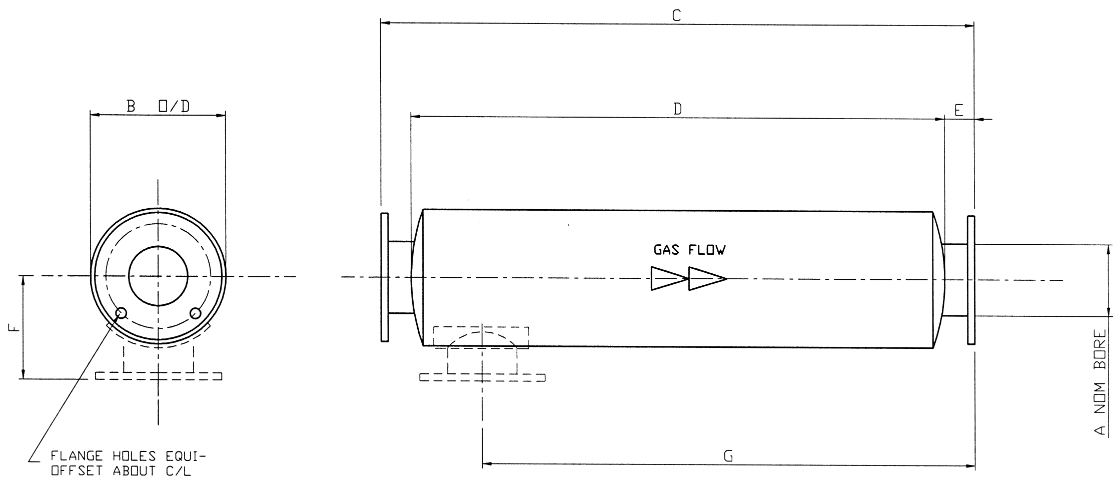


BS TABLE D FLANGE DETAILS					
NOMINAL BORE	FLANGE O/DIA	FLANGE DEPTH	P.C.D.	HOLE	NUMBER of HOLES
100	216	13	178	17.5	4
150	280	13	235	17.5	8
200	336	13	292	17.5	8
300	457	16	406	22	12

NOTE: 3" BORE SILENCERS HAVE 3" BSP/MALE STUBS INSTEAD OF FLANGES

Used on	Part No.	Dim A	Dim B	Dim C	Dim D	Dim E	Dim F	DimG
B3.3	X0791921	75 (3")	152	780	680	50	126	670
4B, 6B	015322	75 (3")	152	780	680	50	/	/
4B, 6B	015308	75 (3")	152	/	680	50	126	670
6C	015323	100	260	900	800	50	/	/
6C	015319	100	260	/	800	50	180	745
L, N, K19, V28, K38, Q30	015324	150	375	1250	1100	75	/	/
L, N, K19, V28, K38, Q30	015320	150	375	/	1100	75	255	1050
QSX15	01553491	200	567	1750	1600	75	360	1400
K50, K19G4, K38G4/5, Q30G4/8	015325	200	413	1550	1400	75	/	/
K50, K19G4, K38G4/5, Q30G4/8	015321	200	413	/	1400	75	285	1310
QSK60	01553431	300	575	2200	2000	100	385	1825

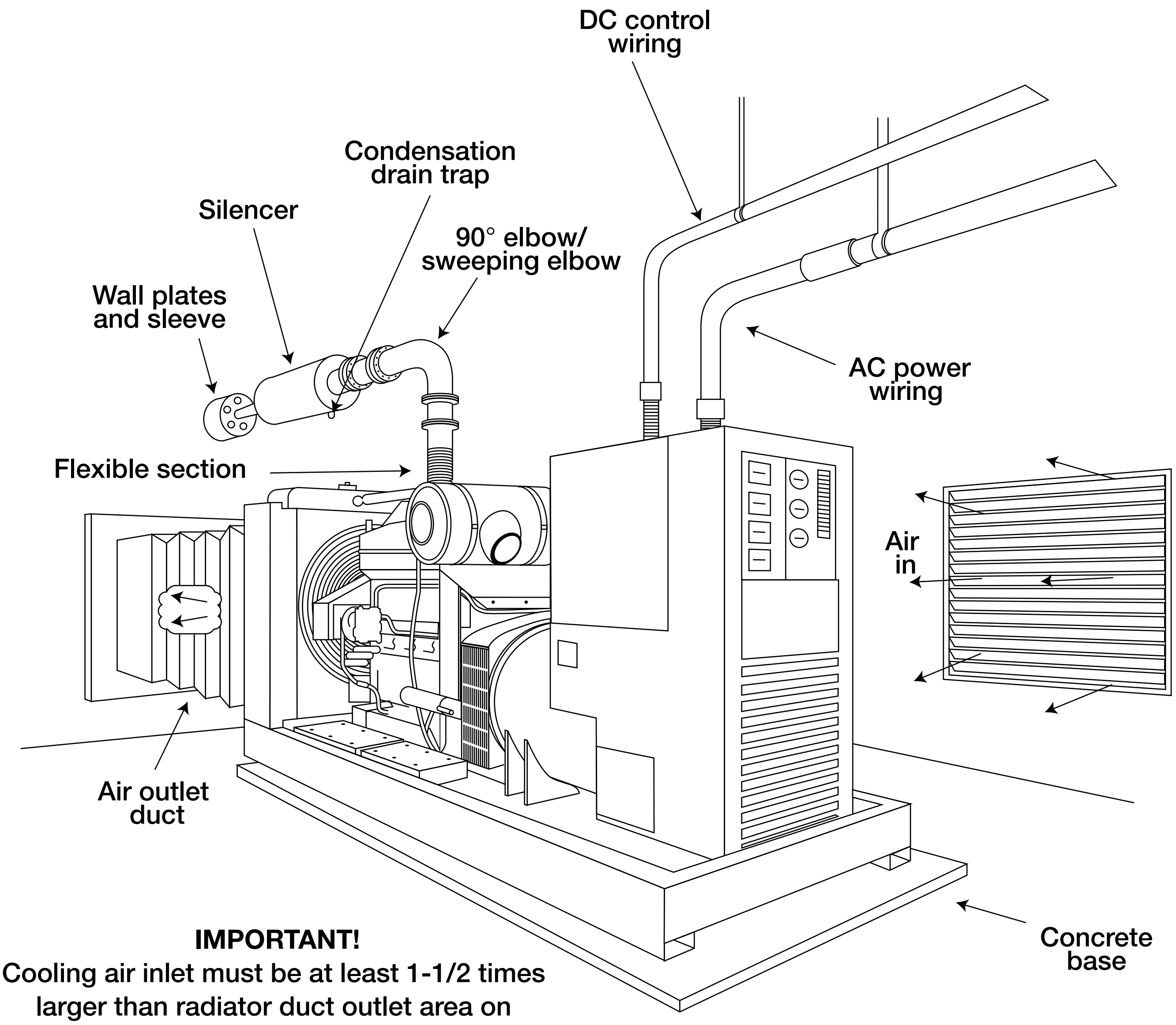
GA of Exhaust Silencers (Residential)



BS TABLE D FLANGE DETAILS					
NOMINAL BORE	FLANGE O/DIA	FLANGE DEPTH	P.C.D.	HOLE	NUMBER of HOLES
100	216	13	178	17.5	4
150	280	13	235	17.5	8
200	336	13	292	17.5	8
300	457	16	406	22	12

NOTE: 3" BORE SILENCERS HAVE 3" BSP/MALE STUBS INSTEAD OF FLANGES

Used on	Part No.	Dim A	Dim B	Dim C	Dim D	Dim E	Dim F	DimG
B3.3	X0791922	75 (3")	260	750	650	50	180	590
4B, 6B	015313	75 (3")	260	750	650	50	/	/
4B, 6B	015309	75 (3")	260	/	650	50	180	590
6C	015314	100	304	900	800	50	/	/
6C	015310	100	304	/	800	50	205	712
L, N, K19, V28, K38, Q30	015315	150	413	1350	1200	75	/	/
L, N, K19, V28, K38, Q30	015311	150	413	/	1200	75	285	1070
K50, QSX15, K19G4, K38G4/5, Q30G4/8	015316	200	567	1750	1600	75	/	/
K50, QSX15, K19G4, K38G4/5, Q30G4/8	015312	200	567	/	1600	75	360	1400
QSK60	01553433	300	750	2600	2400	100	470	2075



Typical Installation

Silencer Selection

There are three common attenuation categories;

Industrial (or Non-Critical)	12 to 18 dBA attenuation
Residential	18 to 25 dBA attenuation
Critical	25 to 35 dBA attenuation

Industrial silencers will generally be acceptable in applications where the noise background is relatively high or on an isolated site. The Residential and Critical silencers are mainly recommended for areas where noise levels, in office blocks, hospitals, etc., are preferred. Remember these silencers will only affect exhaust noise. Sets should be completely silenced to achieve critical noise control.

General

Cooling and ventilation of an engine room is very important. Provision must be made for an adequate air flow through the room, to replace the air consumed by the engine, and air pushed out by the cooling radiator fan.

There are various types of cooling systems that can be adopted, the main ones being as follows.

Set mounted radiator.

Remotely positioned radiator.

Heat exchanger cooling.

IMPORTANT
Radiator Cooled Sets

When the radiator is plant mounted, it should be in line with the outlet attenuator and a duct fitted between.

The minimum cross sectional area of the ducting must be the same as the cooling area of the radiator. A canvas duct with mating steel flanges to suit radiator and output louvres is normally adequate for this purpose.

Ducting bends should be 3 times pipe diameter and where long runs are required the ducting must be enlarged to reduce back pressure on the radiator. Sound attenuated ducts require long runs and have to be designed specifically for each building.

The air inlet and outlet apertures in a building are normally louvred or screened with mesh. The free area taken up by the louvring slats or mesh must be taken into consideration when calculating size of aperture.

The large volume of air required by a diesel engine for cooling and combustion is not always appreciated and it is recommended that the total area of incoming air vents should be 1½ to 2 times larger than the radiator area. All vents should be protected against the ingress of rain and snow. In cold climates where sets are employed on standby duty and only run occasionally, the room should be kept warm. Air inlets and radiator outlets should be provided with adjustable louvres that can be closed when the set is not in use. Thermostatically controlled immersion heaters are generally fitted in the engine coolant system on automatic mains failure sets, as standard.

Dampers

Dampers or louvres protect the genset and equipment room from the outside environment. Their operation of opening and closing should be controlled by operation of the genset.

In cooler climates movable or discharge dampers are used. These dampers allow the air to be recirculated back to the equipment room. This enables the equipment room to be heated while the genset engine is still cold, increasing the engine efficiency.

Radiator Set Requirements

Radiator set cooling air is drawn past the rear of the set by a pusher fan that blows air through the radiator. Locate the air inlet to the rear of the set.

The radiator has an air discharge duct adapter flange. Attach a canvas or sheet metal duct to the flange and the air outlet opening using screws and nuts that duct can be removed for maintenance purposes. The duct prevents circulation of heated air. Before installing the duct, remove the radiator core guard.

Standard Radiator Cooling uses a set mounted radiator and engine pusher fan to cool engine water jacket. Air travels from the generator end of the set, across the engine and out through the radiator. An integral discharge duct adapter flange surrounds the radiator grille.

Remote Radiator Cooling (Optional) substitutes a remote mounted radiator and an electrically driven fan for the set mounted components. Removal of the radiator and the fan from the set reduces noise levels without forcing dependence on a continuous cooling water supply. The remote radiator installation must be completely protected against freezing.

Before filling cooling system, check all hardware for security. This includes hose clamps, capscrews, fittings and connections. Use flexible coolant lines with heat exchanger, standpipe or remote mounted radiator.

Ventilation

Ventilation of the generator room is necessary to remove the heat and fumes dissipated by the engine, generator and its accessories and to provide combustion air.

Factory-mounted Radiator Ventilation

In this configuration the fan draws air over the set and pushes it through the radiator which has flanges for connecting a duct to the out-of-doors. Consider the following:

- See the Generator Set Data Sheet for the design airflow through the radiator and allowable airflow restriction. **The allowable air flow restriction must not be exceeded.** The static pressure (air flow restriction) should be measured to confirm, before the set is placed in service, that the system is not too restrictive, especially when ventilating air is supplied and discharged through long ducts, restrictive grilles, screens and louvers.
- Note that the inlet duct must handle combustion air flow (see the Set Data sheet) as well as ventilating air flow and must be sized accordingly.
- Louvres and screens over air inlet and outlet openings restrict air flow and vary widely in performance. A louvre assembly with narrow vanes, for example, tends to be more restrictive than one with wide vanes. The effective open area specified by the louvre or screen manufacturer should be used.
- The airflow through the radiator is usually sufficient for generator room ventilation. See the example calculation for a method of determining the air flow required to meet room air temperature rise specifications, if any.
- Because the radiator fan will cause a slight negative pressure in the generator room, it is highly recommended that combustion equipment such as the building heating boilers not be located in the same room as the generator set. If this is unavoidable, it will be necessary to determine whether there will be detrimental effects, such as backdraft, and to provide means (extra large room inlet openings and/or ducts, pressurising fans, etc.) to reduce the negative pressure to acceptable levels.

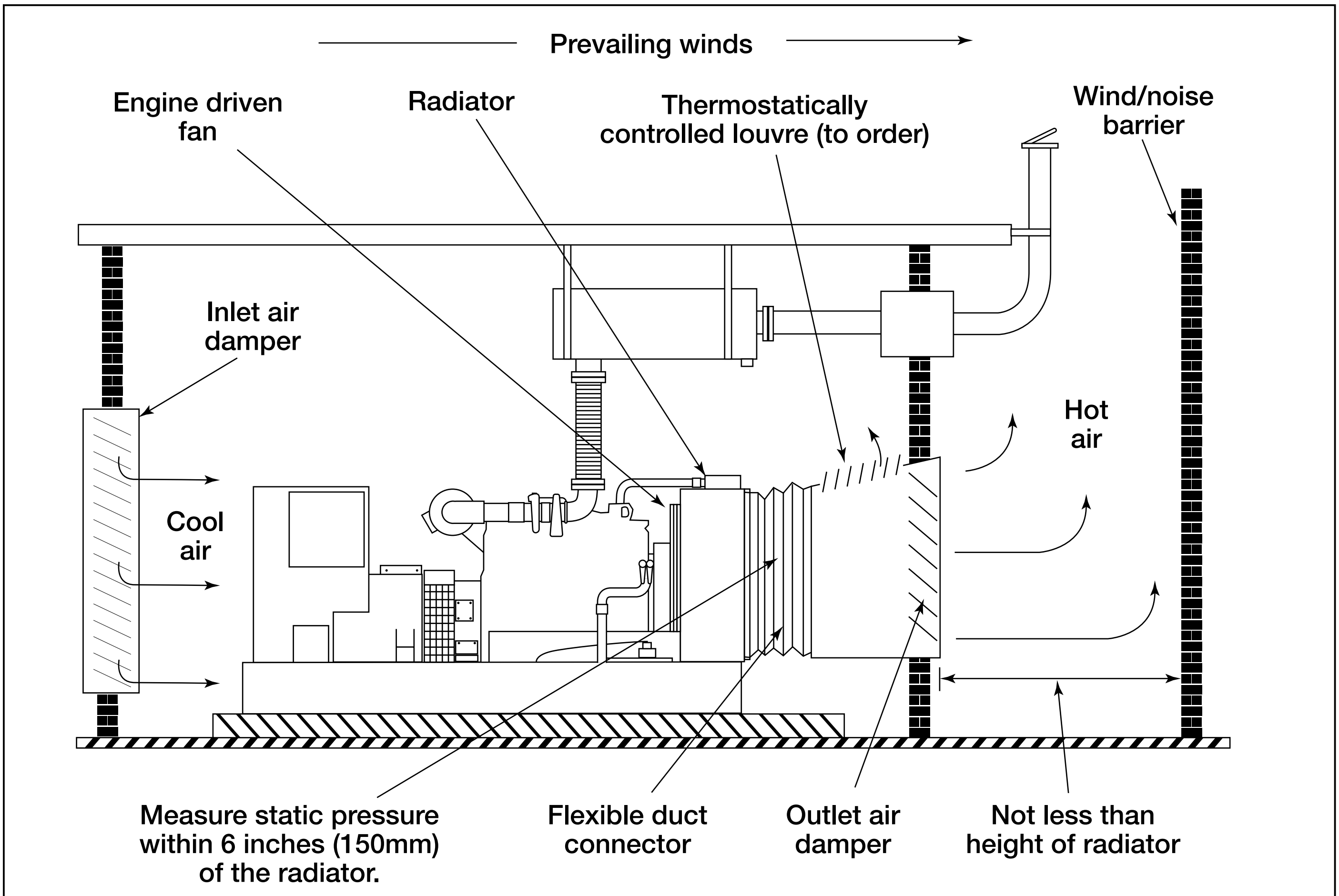


Fig. C15 Factory-Mounted Radiator Cooling

- In colder climates, automatic dampers should be used to close off the inlet and outlet air openings to keep the generator room warm when the set is not running.
- Other than recirculating radiator discharge air into the generator room in colder climates, all ventilating air must be discharged directly to the out-of-doors. It must not be used to heat any space other than the generator room.
- A flexible duct connector must be provided at the radiator to take up generator set movement and vibration and prevent transmission of noise.
- Ventilating air inlet and discharge openings should be located or shielded to minimize fan noise and the effects of wind on airflow.

Engine room ventilation can be estimated by the following formulas:

$$V\ (\text{cfm}) = \left(\frac{H}{0.070 \times 0.24 \times \Delta T}\right) + \text{Engine Combustion Air}$$

or

$$V\ (\text{m}^3/\text{min}) = \left(\frac{H}{1.099 \times 0.017 \times \Delta T}\right) + \text{Engine Combustion Air}$$

V = Ventilating air (cfm) (m^3/min).

H = Heat radiation (Btu/min) (kW).

ΔT = Permissible temperature rise in engine room (°F) (°C).

Density of air at 100°F = 0.070 lb/cu ft (1.099 kg/m^3).

Specific heat of air = 0.24 Btu/°F (0.017 kW/°C).

Assuming 38°C (100°F) ambient air temperature.

Example Ventilating Air Flow Calculation: The generator set Specification Sheet indicates that the heat radiated to the room from the generator set (engine and generator) is 4,100 BTU/min (72 kW). The silencer and 10 feet of 5-inch diameter exhaust pipe are also located inside the generator room. Determine the air flow required to limit the air temperature rise to 30°F.

1. Add the heat inputs to the room from all sources. Table 11 indicates that the heat loss from 5-inch exhaust pipe is 132 BTU per min per foot of pipe and 2,500 BTU per min from the silencer. Add the heat inputs to the room as follows:

Heat from Generator Set	4,100
Heat from Exhaust Pipe 10 x 132	1,320
Heat from Silencer	2,500
TOTAL HEAT TO GENERATOR ROOM (Btu/Min)	**7,920**

2. The required air flow is proportional to the total heat input divided by the allowable room air temperature rise:

$$\text{Required Air Flow} = \frac{59.5 \times \text{Total Heat}\left(\frac{\text{Btu}}{\text{Min}}\right)}{\text{Temp Rise }(\Delta°\text{F})} = \frac{58 \times 7{,}920}{30} = 15{,}312 \text{ cfm}$$

PIPE DIAMETER INCHES (mm)	HEAT FROM PIPE BTU/MIN-FOOT (kJ/Min-Metre)	HEAT FROM SILENCERS BTU/MIN (kJ/Min)
1.5 (38)	47 (162)	297 (313)
2 (51)	57 (197)	490 (525)
2.5 (64)	70 (242)	785 (828)
3 (76)	84 (291)	1,100 (1,160)
3.5 (98)	96 (332)	1,408 (1,485)
4 (102)	108 (374)	1,767 (1,864)
5 (127)	132 (457)	2,500 (2,638)
6 (152)	156 (540)	3,550 (3,745)
8 (203)	200 (692)	5,467 (5,768)
10 (254)	249 (862)	8,500 (8,968)
12 (305)	293 (1,014)	10,083 (10,638)

Fig. C16 Heat Losses from Uninsulated Exhaust Pipes and Silencers

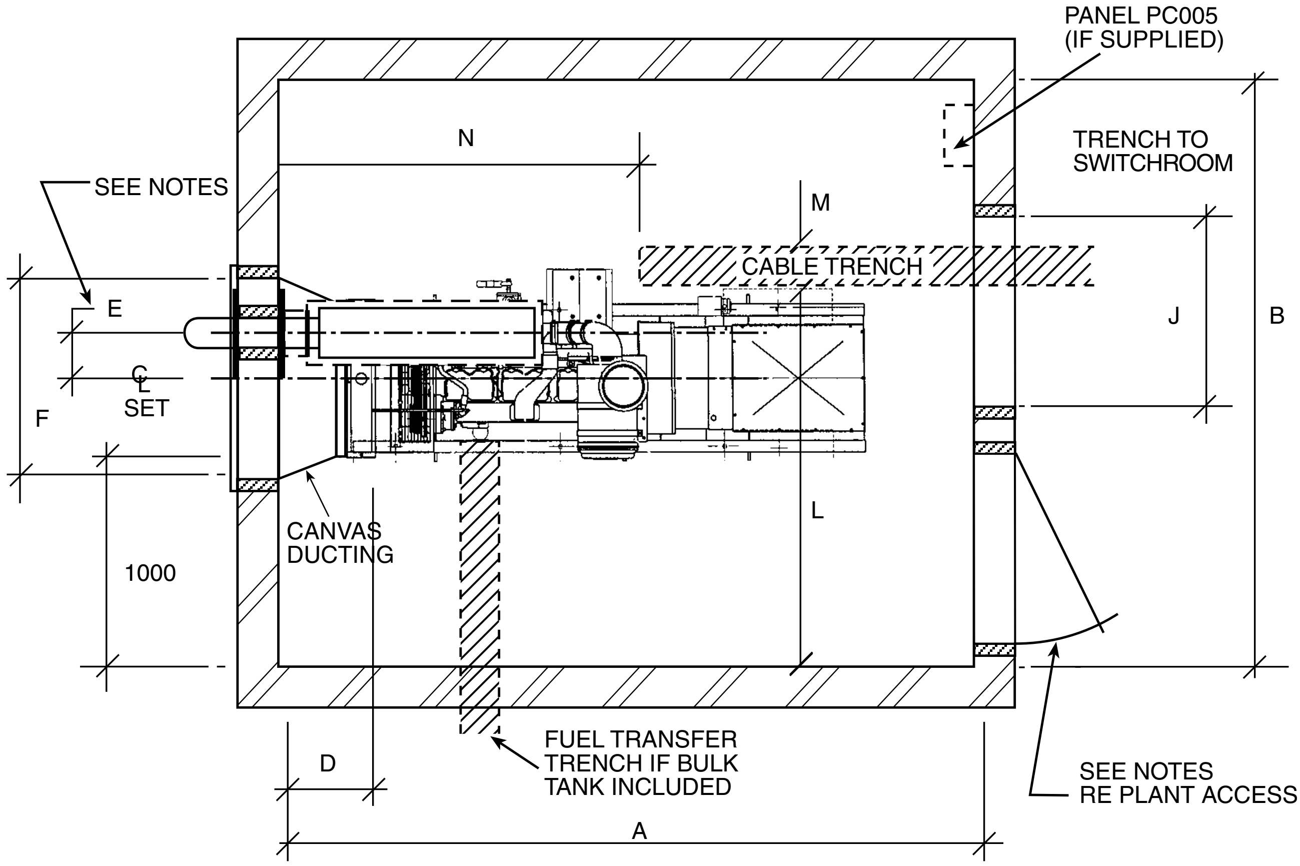
Guide to Heat radiated to room from Engine and Alternator		
	kW/min	
Engine	@50Hz	@60Hz
B3.3G1	15.4	13.1
B3.3G2	15.4	21.1
4B3.9G	10.8	11.4
4BT3.9G1	13.1	15
4BT3.9G2	15	17
4BTA3.9G1	15.5	18
6BT5.9G2	22	25
6CT8.3G2	34	36
6CTA8.3G2	35	40
6CTAA8.3G1	30	N/A
LTA10G2	41	50
LTA10G3/G1	46	55
NT855G6	57	N/A
NTA855G4/G2	65	72
NTA855G3	N/A	76
QSX15	50	80
KTA19G2	N/A	85
KTA19G3	79	95
KTA19G4	88	99
VTA28G5	114	133
QST30G1	126	153
QST30G2	137	166
QST30G3	137	152
QST30G4	152	N/A
KTA38G4	N/A	197
KTA50G3	176	229
KTA50G8	210	N/A
KTA50G9	N/A	224
QSK60G3	318	N/A
QSK60G4/6	300	252

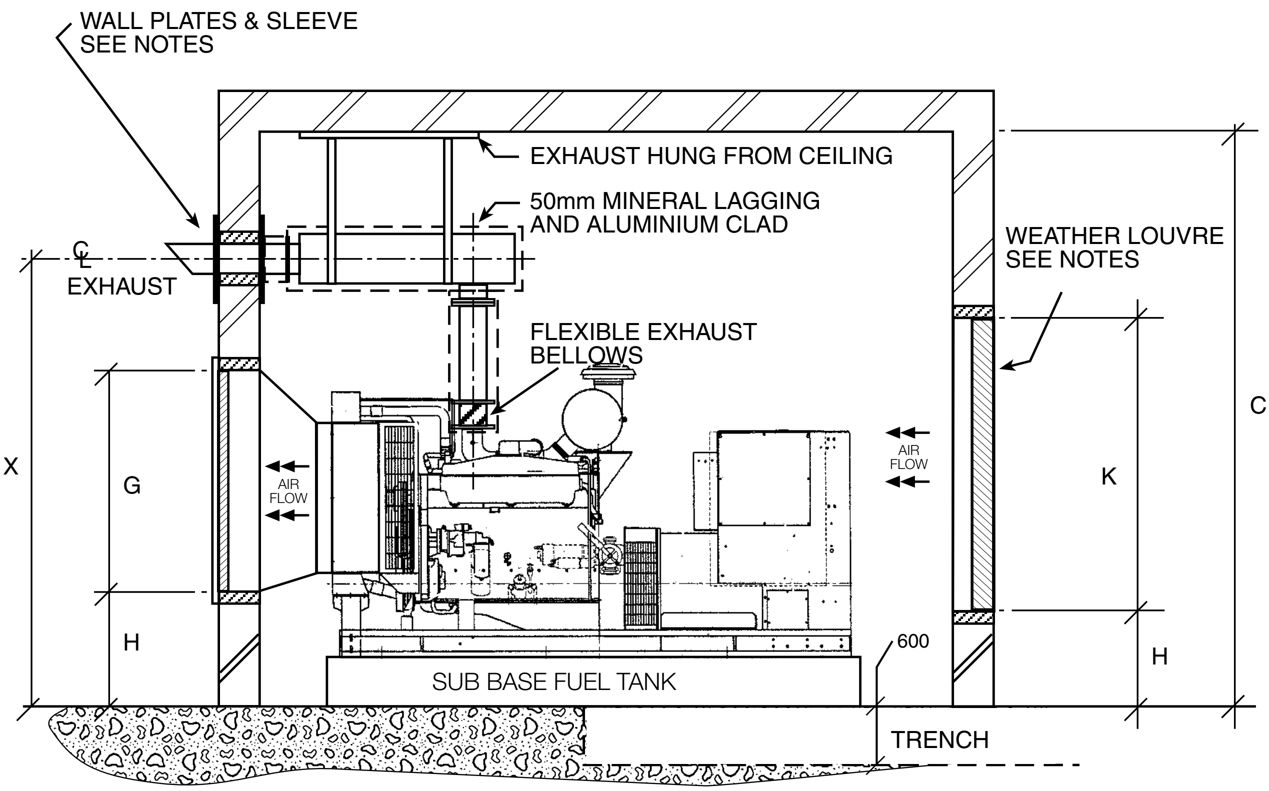
1 kW/min = 56.8 Btu/min

Fig. C17

Cummins Generating Sets 37 KVa - 511 KVa – exhaust run and radiator cooling

Generator room layout without Acoustic Treatment (see page B6 for table dimensions)





Remote Radiator Cooled Systems

Where space in a below ground level installation precludes the use of ducting a number of alternative methods of cooling are available.

A separate radiator system which can be constructed as shown in figure 18. The radiator in this system is separated from the engine and the fan driven by an electric motor.

The radiator with an electric driven fan can be supplied as a totally enclosed unit for outside use, or an open type for installation inside a building

When the radiator is mounted more than 3.0 metres higher than the set, on most engines a break tank and an electric driven water pump is required. The size of the break tank depends on the capacity of the entire cooling system.

Water is circulated from the break tank through the radiator and engine by means of an electrically driven circulating pump.

As the radiator electric fan motor and water circulating pump are powered by the generator, this load requirement must be added to the total set power.

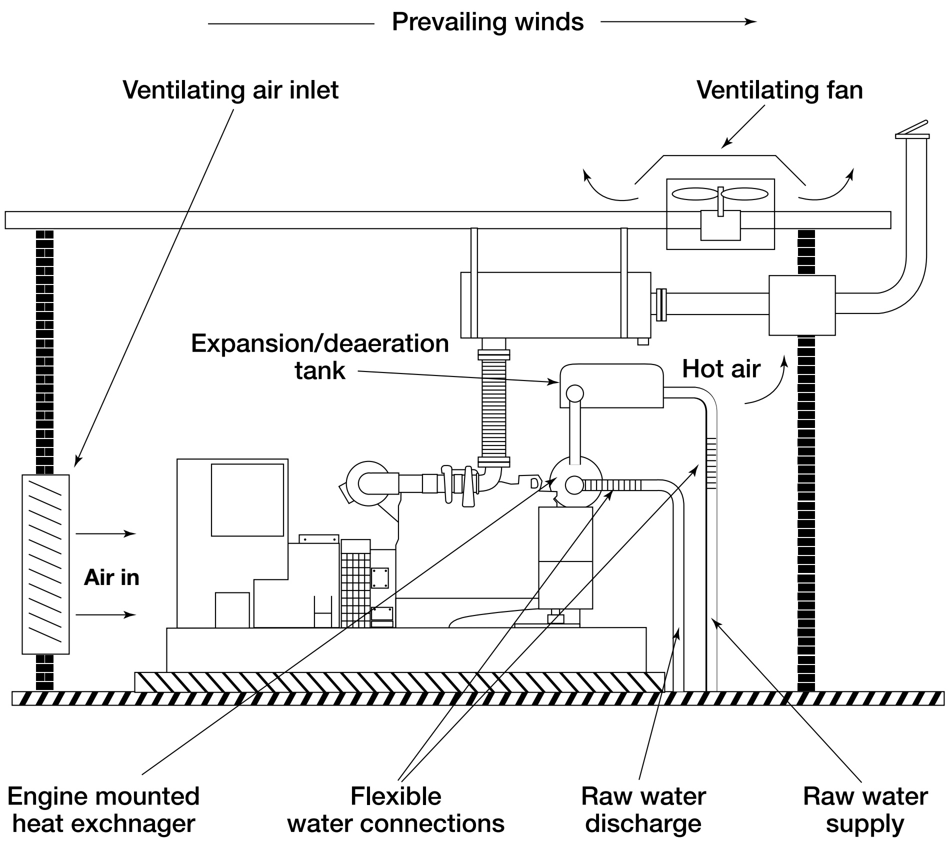
As the water from the radiator will drain into the break tank when the set is at rest, the tank must have sufficient capacity to fill the entire cooling system when the set is running, and still retain enough coolant for it to circulate efficiently.

Precautions Required with this System

The following precautions are required:

1. Against contamination of coolant water by foreign matter.
2. Water becoming oxygenated through turbulence in break tank.
3. Avoidance of air locks in system (pipes should have vent points).
4. Suitable water treatment to engine manufacturers' recommendations.
5. Protect against freezing.
6. Engine runs virtually unpressurised.

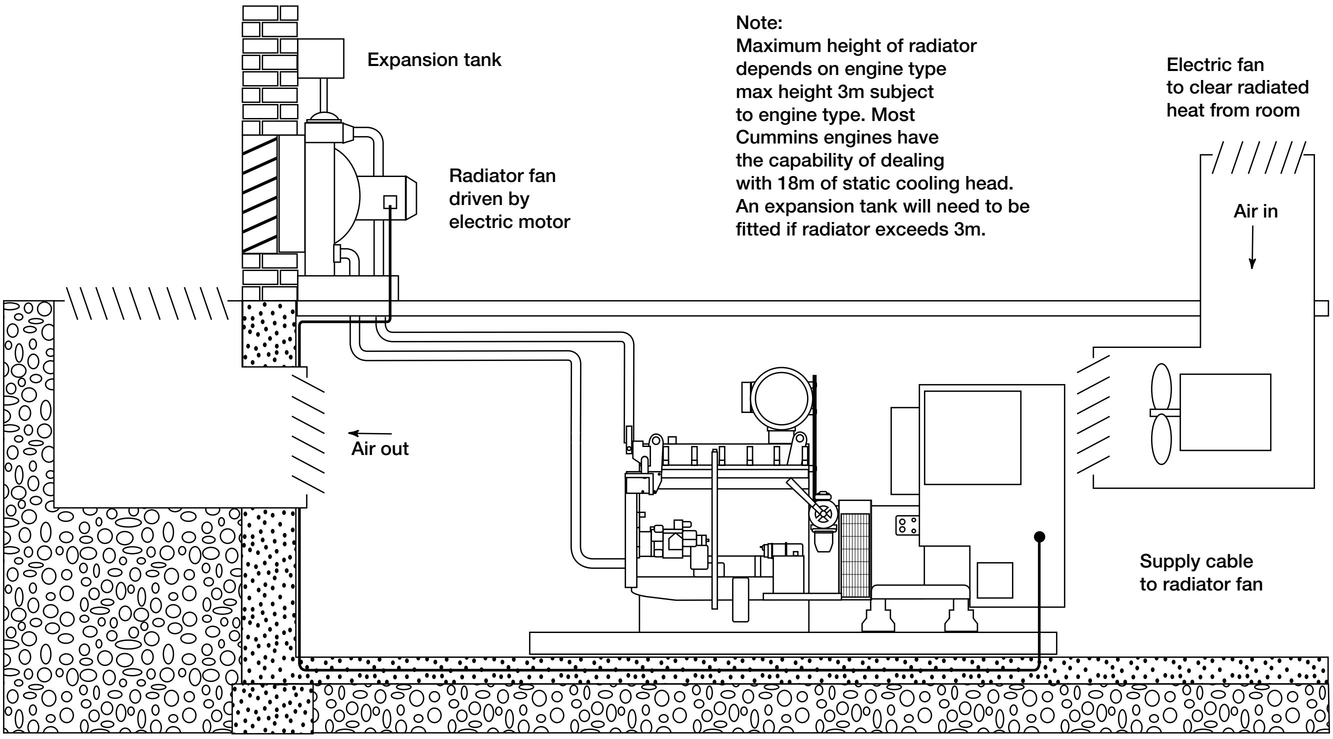
If the radiator is mounted at the same level as the engine and no break tank is required, an expansion tank should be fitted just above the radiator to allow for the expansion of the coolant water.



FACTORY-MOUNTED HEAT EXCHANGER COOLING AND VENTILATION FLOW

Fig. C17

REMOTE RADIATOR COOLING



REMOTE RADIATOR COOLING – HIGH LEVEL

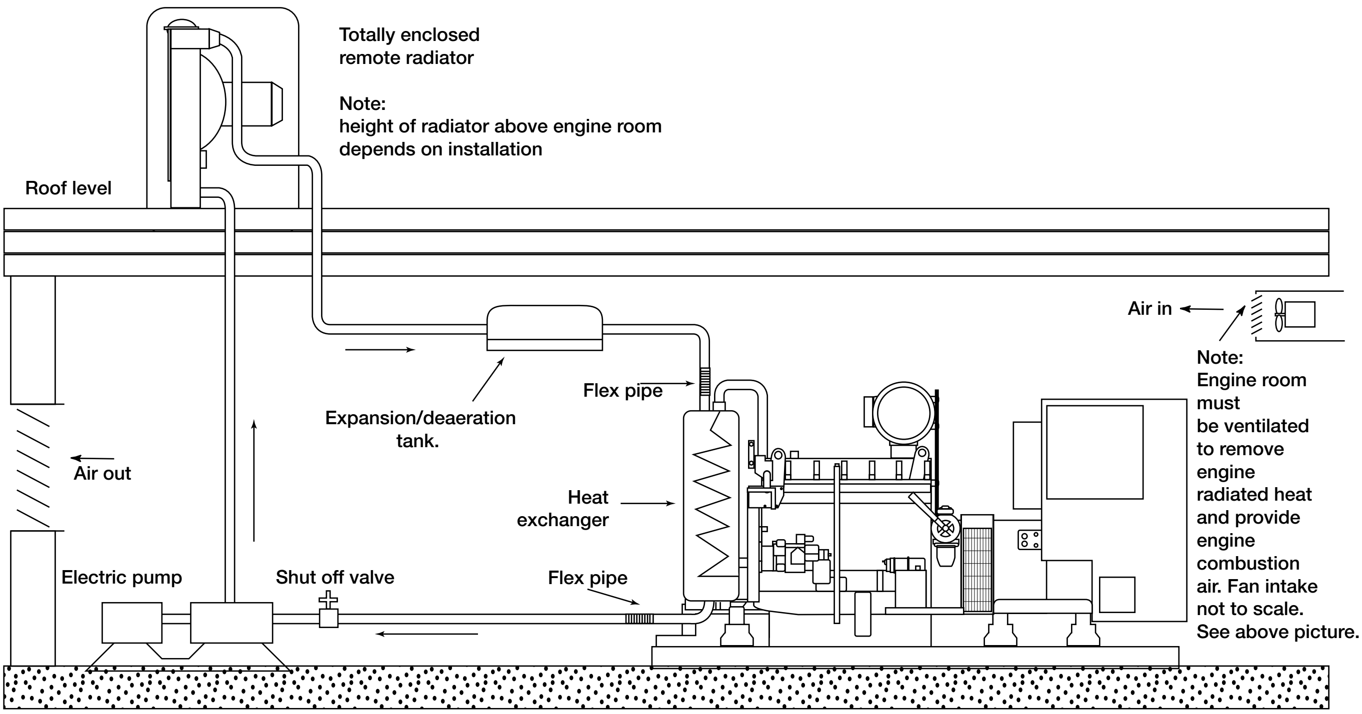
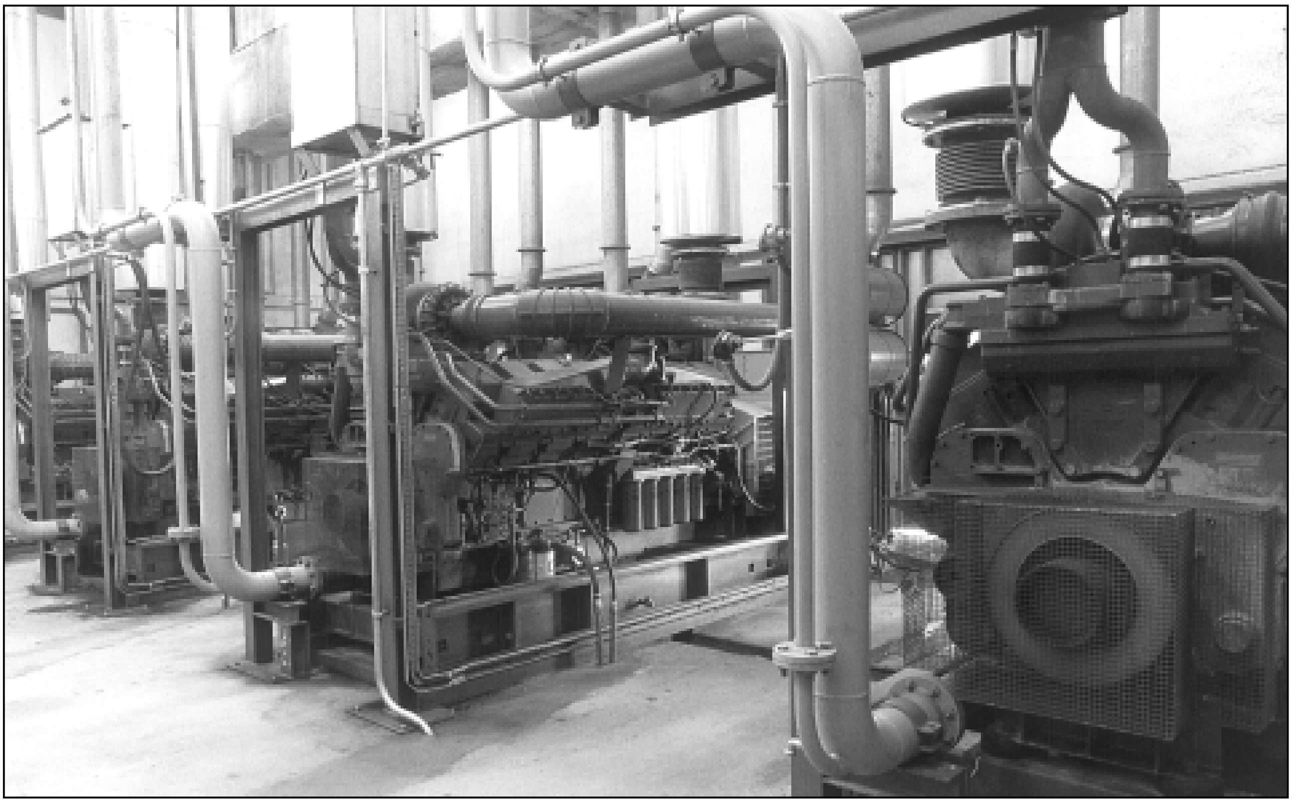


Fig. C18



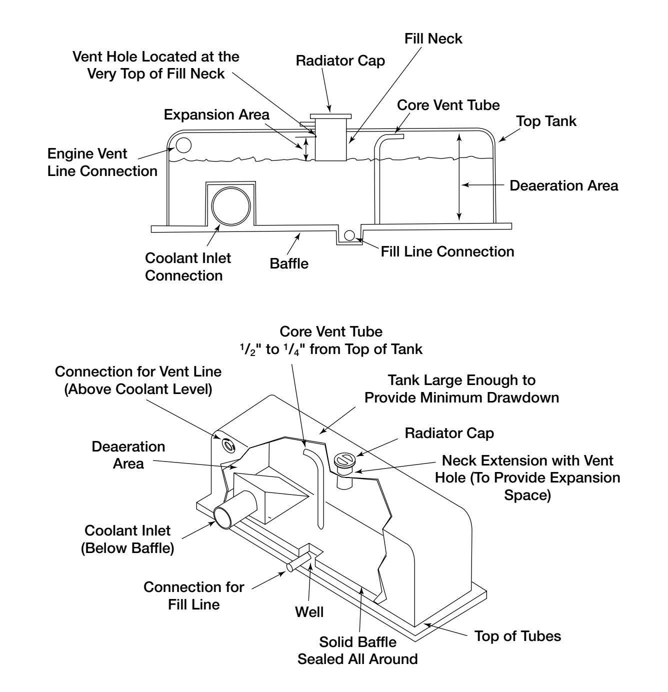
Four heat exchange cooled KTA50 Powered 1256 kVA sets run continuously for a factory in Spain.

Where sets are in basement areas flexible trunking direct to the air intake cleaner ensures a cool supply.

Expansion/Deaeration Tanks

Figs 17 and 18 illustrate provision for an expansion/ deaeration tank above the heat exchanger. In general there are included with the heat exchanger, alternatively you may need to arrange the fabrication of this tank.

Components of Expansion/Deaeration Top Tanks



Cooling system must be designed so that when a cold system is completely filled there is at least a 6% (max 8%) additional capacity to allow for coolant expansion when it is at operating temperature with the correct coolant concentration. This extra volume is obtained by proper location of the FILL NECK. The distance between the underside of the roof of the tank and the bottom of the fill neck is the area in the tank used for expansion of the fluid when it is heated, i.e. at least 6% of the total system volume.

Heat Exchanger

In situations where a constant source of cold water is available, such as a reservoir or river, a heat exchanger can be fitted to cool the engine. However, where direct water cooling is used the quality of the water has an important bearing on the life of the engine. Natural water, such as that from rivers, lakes, reservoirs and ponds can carry scale forming impurities so the raw water should be passed through the tubes of the heat exchanger. The raw water is passed through the tubes rather than the engine coolant because the tubes can be cleaned more easily than the outside. It is necessary to establish the composition and quality of the water to ensure correct selection of materials for the tubes.

The heat exchanger should be located within the plant room adjacent to the engine, with a header tank located locally above the height of the engine or heat exchanger. The circulating pump should be located at a low point within the system, as generally the pumps have a greater pushing capacity compared with their lifting ability).

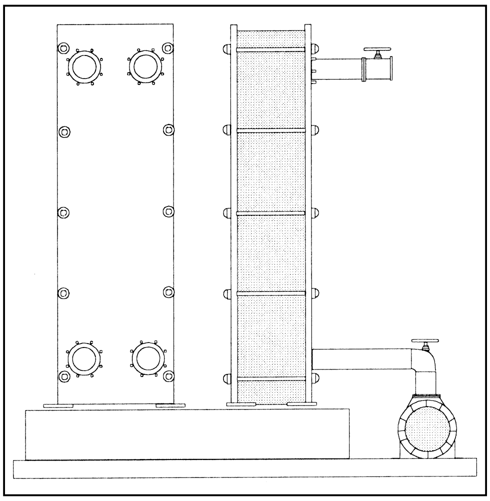


Fig. C19 Heat Exchanger

The heat exchanger pipework recommended should be steel, cast iron or neoprene, or in some cases aluminium, copper or galvanised steel. All connections to the engine should be by means of flexible pipes to avoid the transmission of vibration.

When locating the heat exchanger within the plant room area an allowance should be made for the convected/radiated heat from the units when selecting the ventilation fans.

Cooling Tower

Where, due to site limitations such as high ambient air temperature, it is not practical to cool the engine by means of a standard package, and there is an adequate raw water supply and where wet bulb temp is relatively low, a cooling tower can be used in conjunction with a heat exchanger. Under these circumstances the cooling tower, heat exchanger and circulating pump would need to be selected to form a matched system. The pump should provide the required flow rate whilst overcoming the resistance's of the heat exchanger, the cooling tower and interconnecting pipework.

The raw water, after passing through the engine heat exchanger, is pumped to the cooling tower where the heated water is cooled by running over slats into a reservoir. The cooled water is then returned to the engine heat exchanger. To aid the cooling, a motor operated fan, may be required depending on the size of the tower and amount of water to be cooled. For optimum efficiency, the water circulating pump for the cooling tower, should also be mounted within the plant room adjacent to the heat exchanger. The cooling tower should be located in a convenient position outside the plant room.

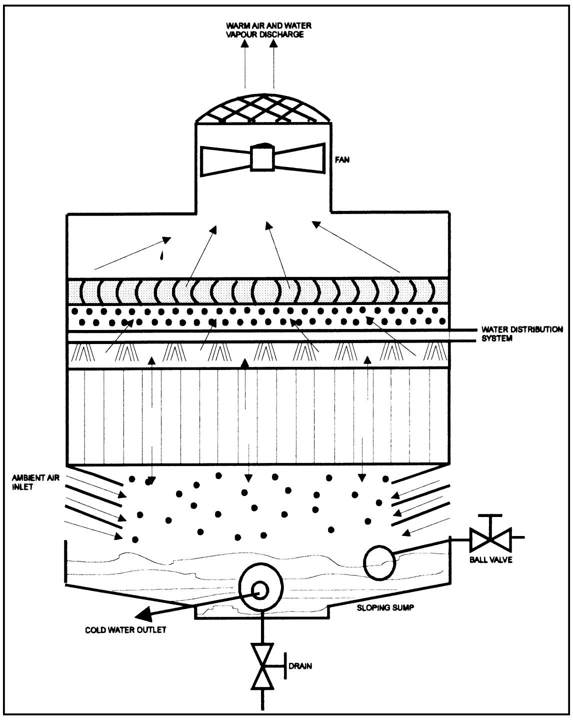
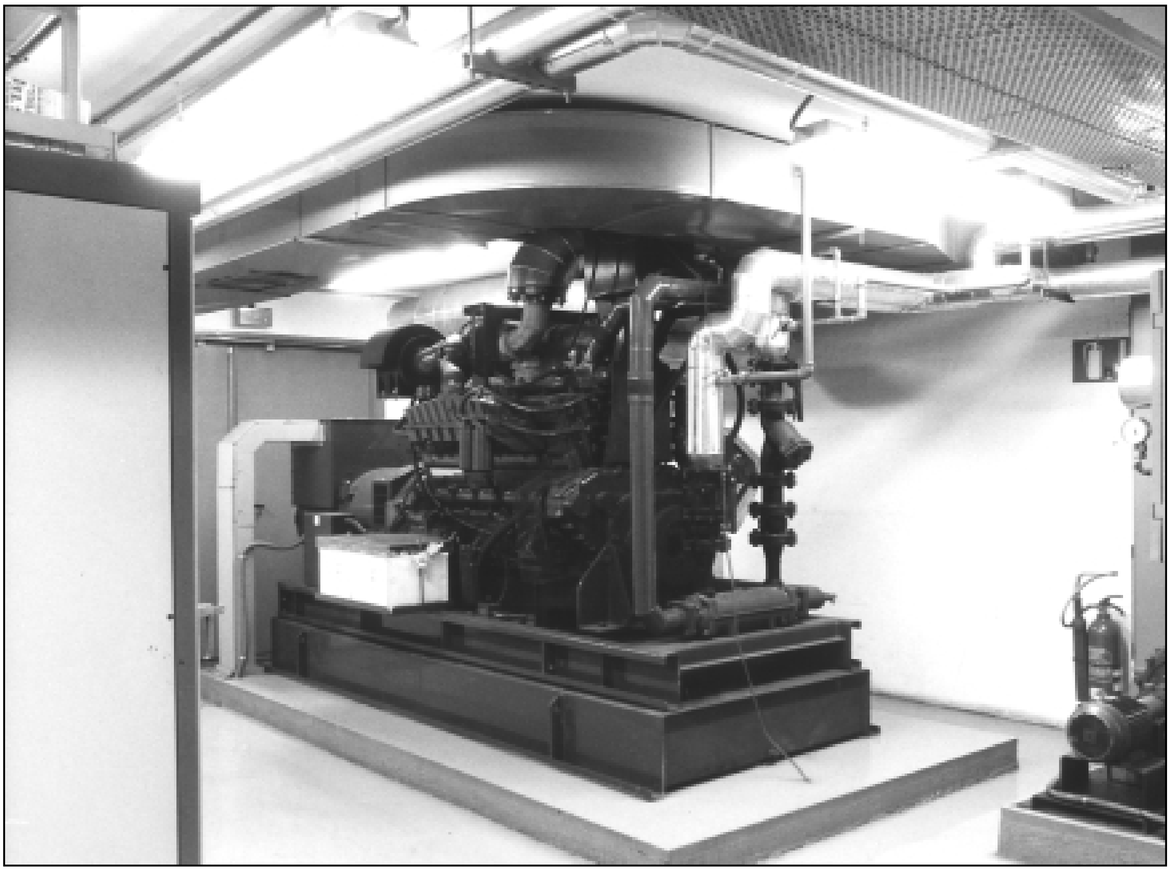
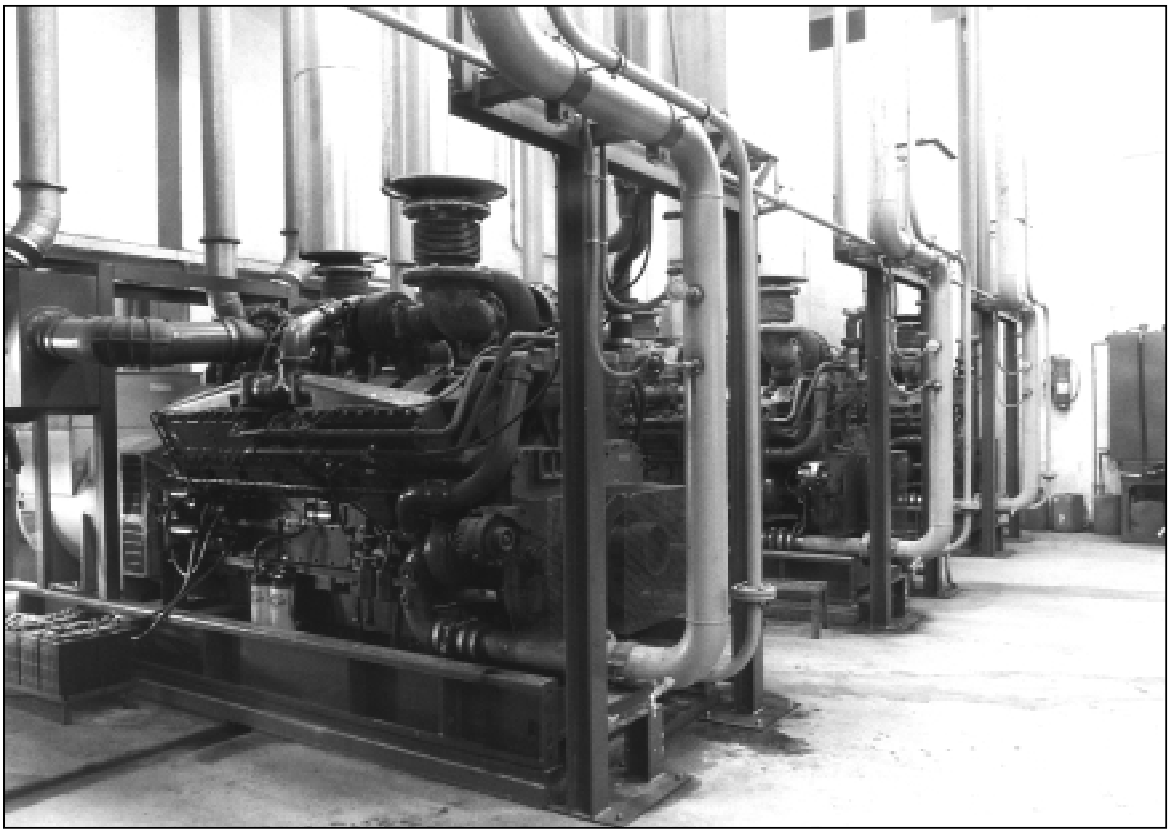


Fig. C20 Cooling Tower



Example of 600 kW Heat Exchanger Cooling Standby Set.



Four set (1 MW) Heat Exchange Cooling Installation for Base Load Operation.

Line Velocities

Water velocity guidelines are as follows:

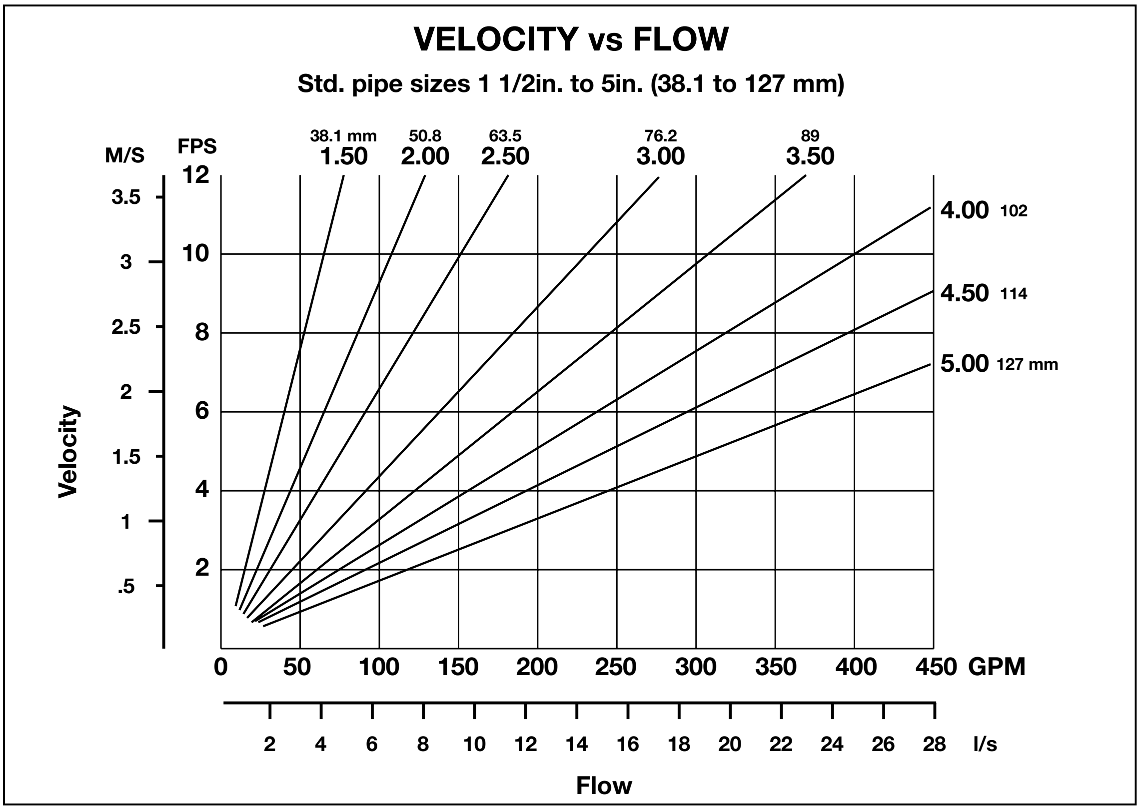
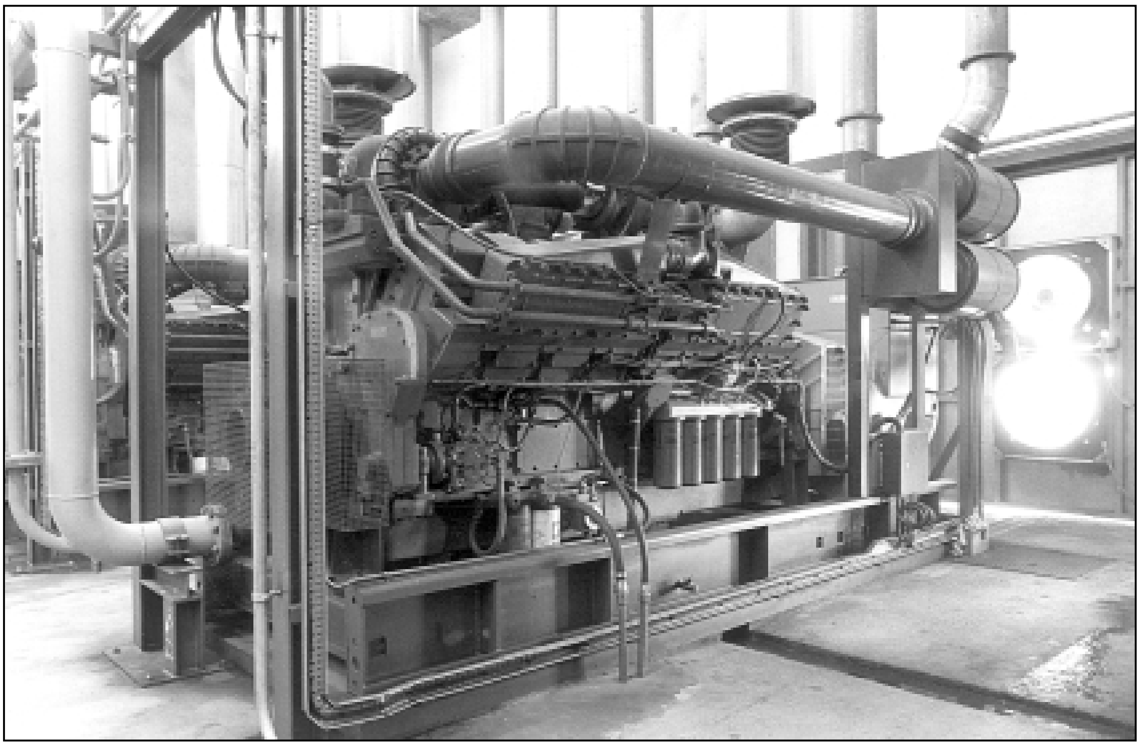


Fig. C23



1250 kVA base power generators with heat transfer system.

General

The engine cooling system is subject to rust and cavitation attacks. To minimise the severity of this condition an anti-corrosive agent can be added to totally clean and limpid coolant water.

An antifreeze solution is also required to prevent freezing of the coolant in the cold weather.

Engine Coolant

Water for coolant should be clean and free from any corrosive chemicals such as chlorides, sulphates and acids. It should be kept slightly alkaline with a pH value in the range 8.5 to 10.5.

Generally, any water which is suitable for drinking can be used, with treatment as described below.

Protection against corrosion

Supplemental Coolant Additive (Cummins DCA4 or equivalent) is required to protect the cooling system from fouling, solder blooming and general corrosion.

The use of antifreeze is also recommended as DCA4 concentrations are dependent upon the presence of antifreeze. Antifreeze also interacts with DCA4 to provide greater corrosion and cavitation protection.

Caution: Allow the cooling system to cool down before removing the radiator cap. Observe the manufacturer's instructions regarding pressurised cooling systems and take great care when removing the pressure cap.

Cold Weather Protection

Antifreeze must be added to the coolant where there is any possibility of freezing to protect the engine from damage due to coolant freezing/unfreezing.

A 50% antifreeze / 50% water mixture is recommended because DCA4 concentrations are dependent upon the presence of antifreeze. The dosage of DCA4 must be increased to higher concentration if antifreeze is not added to the coolant. A low-silicate antifreeze is recommended.

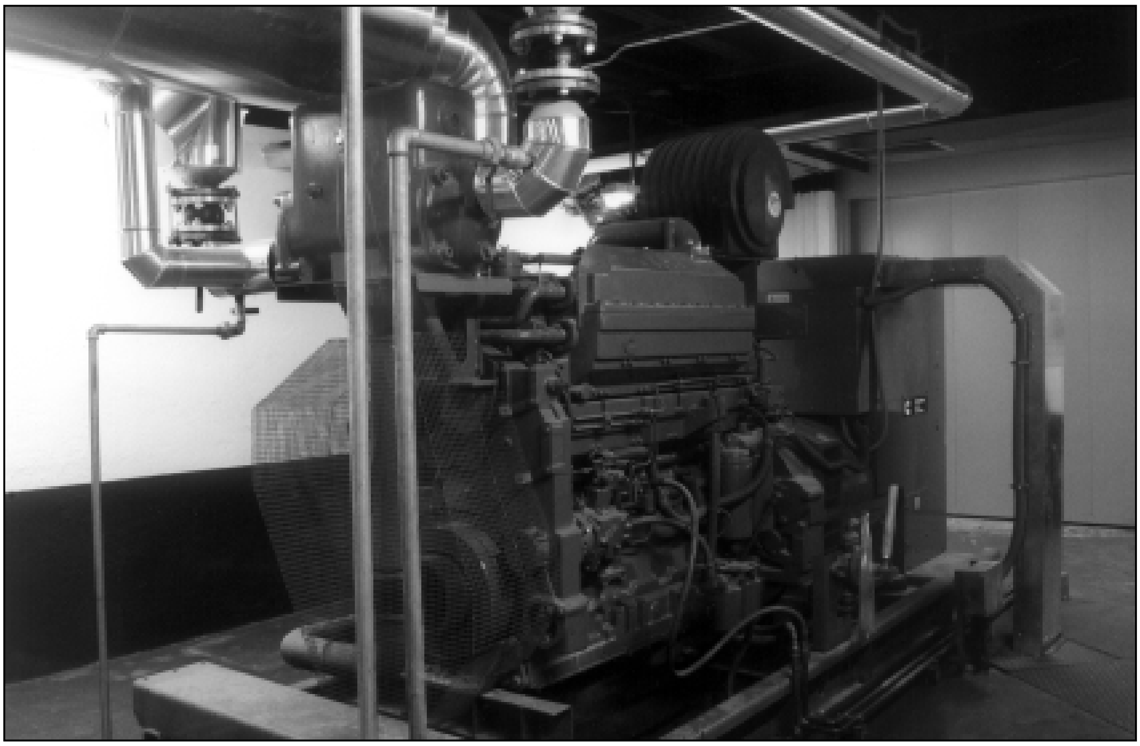
Procedure for Treating Coolant

1. Add the required amount of water to a mixing container and dissolve in the required quantity of DCA.
2. Add the required amount of antifreeze, if used, to the water solution and mix thoroughly.
3. Add the coolant to the cooling system and replace the radiator cap securely.

Engine Warming

Where thermostatically controlled immersion heaters operating from the mains supply are fitted in the cooling system these maintain the temperature of the coolant in cold weather.

A heater alone, fitted in the radiator will not be adequate for starting or preventing freezing, so an antifreeze mixture should be used.



Heat exchanger cooling in a basement location requires extensive inlet and outlet coolant pipework for this 450 kVA generating set powered by the KTA19G engine.

The engine charge combustion and aspirated air system components are as follows:

Air Intake filter (all engines)

Turbocharger (most engines)

The main function of the charge air system is to provide the engine with fresh combustion air of sufficient quality and quantity. An insufficient air supply will cause carbon deposits on the engine components.

Air Intake Filter

Dry Type Air Intake Filter

A dry type air intake filter unit is normally fitted to the engine to prevent the ingress of dirt or dust into the combustion systems.

The intake filter can be supplied loose for mounting on an outside wall of the enclosure or plant room, piped and vented to the air intake system on the engine.

Air Combustion Flows

Refer to Section G Technical Data for engine air combustion flow figures.

Heavy Duty Air Intake Filters

In severe locations such as the desert, heavy duty air intake cleaners are required. They consist of one or more pleated paper elements, which are fire resistant and waterproof. The dust and dirt particles in the air are deposited on the paper fibres, gradually building up to a restrictive limit in which the element must be cleaned or replaced.

In other installations with extreme conditions (cement factories, etc.) the highest allowed particle concentrations at turbocharger inlets are as follows:

Cement dust	10mg/m^3
Calcium hydroxide	5mg/m^3
Chlorine	1.5mg/m^3
Oxides of sulphur	20mg/m^3

Heat Rejection

Whilst the cooling water system detailed in Section 7 serves to remove a substantial amount of the heat produced by the engine, an additional amount is rejected into the room from the following sources:-

The alternator, in terms of direct radiation from the machine body and from its integral fan cooling system

Radiated heat from the engine assembly.

The sections of the exhaust system within the room, especially unlagged sections of pipework or the silencer.

Details of the level of heat rejected to the ambient by the engine and alternator are given on the specification data sheets or in the project technical specification. Heat rejected from the exhaust pipework and manifolds is taken into consideration for the assessment of the total amount of heat that will be dissipated into the plant room. Typically, 10% of the value given in the engine data sheets as **"heat rejected to exhaust"** will cover the exhaust system provided it is lagged.

The ventilation system should be properly designed to limit the temperature rise within the plant room between 10 to15°C (18 to 27°F) above the ambient when operating at full load. If the resultant temperature within the plant room exceeds 40°C the aspiration air should be ducted direct from the atmosphere to the engine, or the engine derated appropriately.

Cooling Air Flow Calculation

Utilising the total heat rejection value, the cooling air flow required through the plant room can be calculated using the following formula:-

$$\textbf{Air Flow (cfm)} = \frac{\text{Rejected Heat (KW) X 58}}{\text{Air Density (0.07) x Specific heat of air (0.238) x Temp Rise (F°)}}$$

Where:

The total kW of heat rejected is sourced from all equipment within the plant room: the engine; the alternator; the exhaust pipework and silencers etc.

The temperature rise is the maximum rise above ambient permissible within the plant room (can vary between 10 to 15°C (18 to 27°F).

Ventilation Fans and Louvres

Where cooling radiators are mounted externally ventilation fans are used to remove this volume of air from the plant room. The air inlet and discharge louvres must be sized for this amount plus the aspiration air requirement (if this is being drawn from within the plant room).

Where the cooling radiator is mounted within the plant room, an aperture should be positioned in an external wall directly in line with the air flow through the radiator. The radiator has a discharge duct adapter in which a canvas flexible duct may be attached, this directs unwanted hot air out of the plant room and prevents re-circulation of the hot air. Re-circulation can also be possible if the inlet and discharge air apertures are too close together.

In some applications it is required to remove the heat losses from the plant room while the generator is at standstill. Inlet and outlet louvres may be motorised to automatically move into the open position when the generator is started, or where the air blast radiator is of the pressure type, the outlet louvres may be gravity operated.

Electric Starting Systems

Electric starting systems are generally used on most gensets.

Electric starting systems employ a starter motor, flange mounted on the flywheel housing and driving the flywheel through a pinion and "Bendix" type gear arrangement. For larger engines, a twin starter arrangement may be used.

The power source for electric starting systems is a 12 or 24VDC battery system. The starting voltage is determined by engine size, 24VDC being used for larger engines to reduce starting current and hence cable size. Control of starting is via a start solenoid which is controlled by the genset control system.

Starter Arrangement

On start up, the "Bendix" gear maintains engagement of the starter motor pinion with the flywheel until the engine reaches self sustaining speed. At that stage a speed sensing device automatically de-energises the start solenoid which removes the supply to the electric starter and starter motor pinion disengages from the flywheel.

Battery Systems

Types of Batteries Used

Batteries are of two types - lead acid and NiCad. Lead acid batteries are generally used, being the least expensive. NiCad batteries are used where longer life, etc., is required.

Installing a Battery System

Batteries are an essential part of any standby generator system and some 90% of all generator failures are due to batteries. It is therefore vital that batteries are stored, commissioned and maintained to the required standards.

On most Cummins Power Generation sets provision is made for lead acid batteries to be fitted on the generator chassis. A battery rack is provided for this purpose. If NiCad batteries are provided the following advice should be followed.

When installing a battery system for an electric starter system consideration should be given to the following:

- Space requirement - for larger gensets the battery system may require a considerable floor area.
- Install the battery system in a clean, well lit, and well ventilated area. If installed in a cubicle, adequate ventilation must be provided. Easy access should be provided for maintenance - for checking electrolyte level, topping up cells, etc.
- NiCad batteries will require periodic rapid discharging/charging to avoid “memory effects”.
- If the battery must be placed on the floor it is necessary to use battens, preferably on insulators. This will raise crates or cell bottoms clear of any damp or dust which may accumulate.
- Avoid installing batteries in a hot area. For optimum efficiency it is preferable to operate all batteries within the range 15°C to 25°C.
- Place crates or tapered blocks of cells in the correct position for connecting-up as a battery. Fit inter-crate, or inter-block connectors and then the main battery leads. Tighten all nuts firmly with a box spanner. Smear the battery terminals with petroleum jelly to prevent corrosion.
- Battery charging system -
  - This may be a charge alternator which charges the batteries only when the set is running, and / or, for standby or automatic start sets,
  - Mains powered battery charger which will maintain the battery system in a charged condition when the set is not running and is powered from a mains supply.

    Note: a mains powered battery charger must be fed with power from a "maintained supply", not from the set output.
- During the charging of a battery, explosive gases are given off.

Caution: Ensure that batteries are charged in a well ventilated area, away from naked flames and sparks.

Caution: When putting a battery into service on a genset, connect the earth lead **LAST;** when removing the battery, disconnect the earth lead **FIRST.**

Caution: Ensure correct polarity when connecting the battery to the genset. Even momentary incorrect connection may cause damage to the electrical system. Connect the positive generator cable FIRST, followed by the negative ground.

Starting Aids

It is customary to maintain coolant temperatures above 40°C min. to promote quick starting on an emergency generating plant. Thermostatically controlled immersion heaters, deriving their supply from the primary source of power, are fitted in the engine cooling system to provide this heating. For severe circumstances it is advisable to include a similar heater for lubricating oil.

Avoid installing lead acid batteries in the same room as NiCad batteries as these will deteriorate due to gaseous fumes from the lead acid batteries.

Verify all electrical connections are secure and all wiring is complete and inspected. Replace and secure any access panels that may have been removed during installation.

Battery Connections

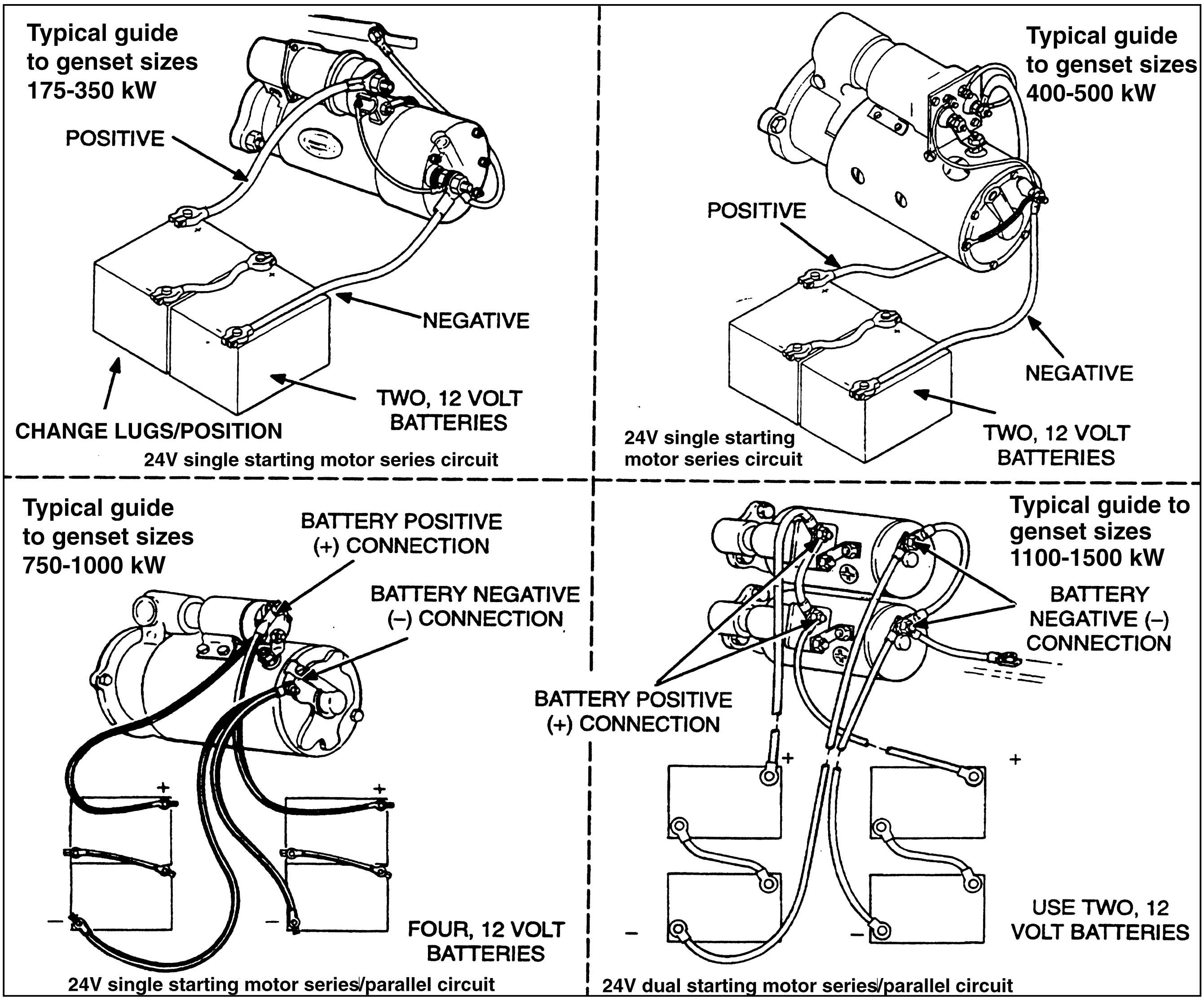
⚠ WARNING ***Accidental starting of the generator set can cause severe personal injury or death. Make sure that the Run/Off/Auto switch on the control panel is set to the Off position before connecting the battery cables.***

Sets with LTA10 engines and above require 24 volt battery current, using two or four, 12 volt batteries (see Specification section). Connect the batteries in series (negative post of first battery to the positive post of the second battery) as shown below.

Service batteries as necessary in accordance with the manufacturers instructions. Infrequent use (as in emergency standby service), may allow battery to self-discharge to the point where it cannot start the unit. If installing an automatic transfer switch that has no built-in charge circuit, connect a separate trickle charger. Cummins automatic transfer switches include such a battery charging circuit.

⚠ WARNING ***Ignition of explosive battery gases can cause severe personal injury. Always connect battery negative last to prevent arcing.***

⚠ WARNING ***Be sure battery area has been well ventilated prior to servicing near it. All batteries emit a highly explosive hydrogen gas that can be ignited by arcing, sparking, smoking, etc.***



175 Through 1500 kW Genset Battery Connections

Legislation to control environmental noise pollution in sensitive areas exists and must be complied with, but generally it will be the local authority who will determine the requirements. Planning must be sought with the local authority to determine the noise level of the equipment. The requirements for noise control will depend on the environmental conditions and operating time at the proposed location of the generating set and associated equipment.

There are two types of noise to be considered:-

Structure borne noise - emanates from the vibrations created by the generating set and associated connected equipment. Minimise this type of noise by use of anti vibration mounts and flexible connections.

Airborne Noise - emanated from the generating set.

Noise Reduction Methods

Reduction of structure borne noise can be achieved by use of anti vibration mountings and flexible hangers and connections. Reductions of airborne noise can be achieved by the use of splitter attenuators, exhaust gas mufflers, acoustic wall and ceiling linings, acoustic inlet and outlet louvres, enclosures and drop over canopies.

In addition the use of slow speed fans within a plant room or an internally mounted heat exchanger with an externally mounted, low noise cooling tower would be advantageous.

Enclosures can be supplied for installing over a generating set within a plant room to isolate the rest of the building from noise.

The noise level at a given location is a resultant from all sources, once the level is known and the site restrictions are known, the sound attenuation louvre sizes and equipment can be considered and selected as required.

Each engine has a noise spectrum for both mechanical noise coming off the block and for the exhaust noise emitting from the end of the pipe. This information, together with the combustion and cooling air flow requirements and maximum pressure restrictions allowable should be provided to the noise attenuation equipment suppliers to size the splitter attenuators required for the inlet and discharge air apertures and silencers for the exhaust gas.

See Section F Silenced Generators.

Noise Legislation

Noise Legislation relating to generators working on construction and building sites exists throughout all countries in the EEC. EEC directive 2000/14/EC.

Outside the EEC

Before installation, it is essential to check each countries legislation and local authority requirements.

Auxiliary AC Supplies

Auxiliary AC supplies must be provided for all auxiliary equipment (e.g., ventilation fans, heaters, pumps, etc.), together with the associated AC distribution panel. A motor control unit (MCC) may be provided where applicable.

Fire Protection

Diesel fuel can be stored safely above ground in suitable containers. Whilst the flash point is high, it is inflammable and suitable fire fighting equipment should be provided.

Provision for fire fighting equipment should be made in the initial design of the plant room. The storage area should be adjacent to an access door, if possible.

Foam or CO^2 should be used for oil fires, i.e. fuel oil, gas, lubricating oils etc.

CO^2 or CTC should be used for electrical fires or near bare conductors.

Sand can be used for minor and isolated fires.

Under **NO** circumstances should water be used to control a fire in the plant room.

Tools

A standard kit of engine tools can be ordered with the plant. They should be protected from corrosion and stored in a safe dry place.

Spares

If spares are supplied with the plant they should be protected against corrosion and stored in a safe dry place.

Plant Room Lighting & Staging

The plant room should be well illuminated to assist manual operations and maintenance. Natural lighting from windows should give good illumination to critical areas. Double glazing on windows will reduce heat loss and emitted noise.

To provide access to elevated items on larger plants it may be necessary to erect suitable staging which must provide safe access.

Maintenance Space

All component parts of the installation should have ample space and access around them to assist maintenance.

The control cubicle should have sufficient free space to enable all access doors and panels to be opened and removed.

Space should be left around the plant to give safe and easy access for personnel.

There should be a minimum distance of 1 metre from any wall, tank or panel within the room.

Generator Control Panels

The generator set is controlled locally by a dedicated Control Panel. These are mounted on the generator but can be remotely sited and floor mounted as an option. Control systems, metering, alarm indications and customer connections are incorporated.

A selection of control systems are designed to meet basic operating controls for single generators through systems up to multiple generator set installations with fully automatic synchronising and networking facilities.

This includes the basic PCL system (as Fig.1), the PowerCommand (PCC) system as Fig.2, the PCC mk11 or the Master Controllers for automatic mains failure or paralleling with either the MC150 PLTE (Fig. 3) or the MC150-4 and the Digital Master Controller DMC (Fig. 4) with extensive control functions and the flexibility to meet paralleled generators in two or multiple set installations.

PCL (Power Control) (Fig. 1)

PCL is a low cost generator set monitoring, metering and control system which provides local control of the generator set and forms part of the main control panel. This control system provides high reliability and optimum generator set performance.

Two versions of PCL are available:

PCL 001 which provides generator set control with manual start.

PCL 002 which provides generator set control with remote start.

Both units provide generator start / stop and indicate operational status. In the event of a fault, the units will indicate the fault condition(s) and in the case of shutdown faults, e.g., low oil pressure, automatically shut down the engine. Faults are indicated by means of LED's.

PCL 002 may be used with an Automatic Transfer Switch (ATS) Control Unit which senses mains failure, supplies a remote start signal to the generator set control unit and provides breaker control.

Fig. 1 Power Control PCL system showing all options fitted including two annunciator units.

An alarm annunciator module, with 6 input channels and 6 corresponding LED's configurable to customer requirements, may be used as a protection expansion unit, an annunciator or a combination of both. Each unit provides two relay outputs. A maximum of two alarm annunciator units modules can be fitted to the generator control panel.

PowerCommand™ Control (PCC) (Fig. 2)

PowerCommand™ Control (PCC) is a microprocessor-based generator set monitoring, metering and control system which provides local control of the generator set. This system provides high reliability and optimum generator set performance.

PCC provides an extensive array of integrated standard control and display features, eliminating the need for discrete component devices such as voltage regulator, governor and protective relays. It offers a wide range of standard control and digital features so that custom control configurations are not needed to meet application specifications. Refer to the Cummins Technical Manual.

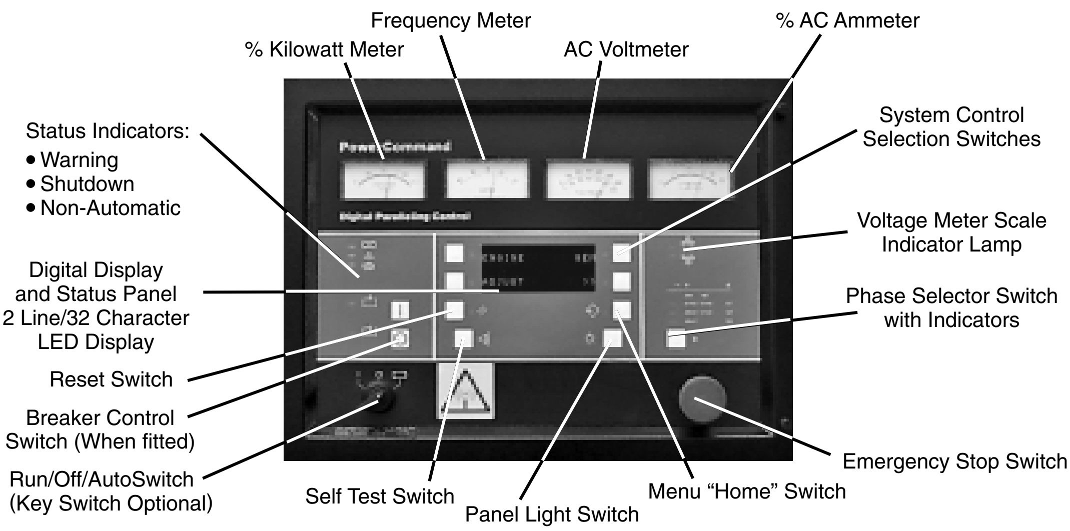


Fig. 2 PowerCommand Control.

Two versions of PowerCommand™ are available:

PowerCommand™ Generator Set Control which provides generator set control for single sets.

PowerCommand™ Generator Set Control Paralleling Version which provides generator set control with paralleling for multi set applications or utility paralleling.

Major Control features include:

- Digital governing, voltage regulation, synchronising and load sharing control.
- Electronic overcurrent alternator protection.
- Analogue and digital AC output metering.
- Digital alarm and status message display.
- Generator set monitoring status display of all critical engine and alternator functions.
- Starting control including integrated fuel ramping to limit black smoke and frequency overshoot with optimised cold weather starting.
- Easy servicing.
- Communications network capability.

Master Controller Model MC150 PLTE (Fig. 3)

Automatic Mains Failure or Utility Paralleling System

System Function

The MC150 PLTE is a configurable controller designed to operate as an Automatic Mains Failure system or a Utility Paralleling system in conjunction with a PowerCommand (PCCP) controlled generating set. The MC150 PLTE has been designed specifically for Infinite Bus applications involving one generator and one Utility.

Fig. 3

Master Controller Model MC150-4 (Fig. 3)

Automatic Paralleling Interface Isolated Bus System Applications

System Function

The MC150-4 is a Configurable Controller designed to operate as a fully automatic interface system to facilitate automatic starting, set to set synchronising and load sharing of up to four PCC (PowerCommand Control) equipped generating sets of equal, or unequal, ratings for continuous Load operation.

PCC Paralleling

Digital MasterControl – DMC (Fig. 4)

Model 300 –
For Infinite Bus Applications

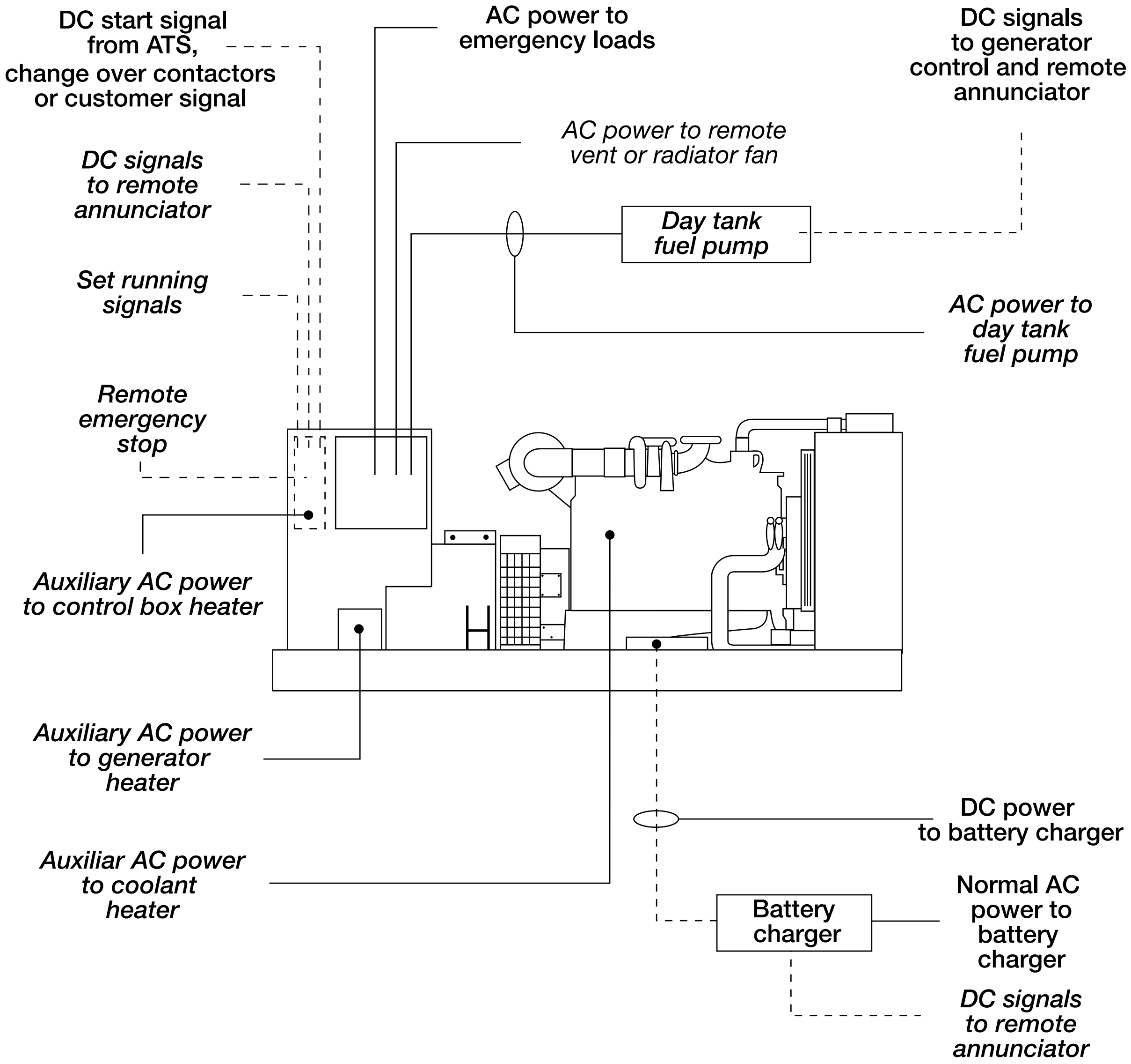
Model 200 – (Fig. 4)
For Isolated Bus Applications

The PowerCommand™ Digital MasterControl is a microprocessor-based paralleling system component, designed to directly interface with Cummins PowerCommand Paralleling generator sets. The Digital MasterControl is designed for use in low or medium voltage isolated bus applications. Model 300 can be used for system supervision of generator sets paralleled to each other (Isolated Bus), or for the paralleling of generator sets to a utility (mains) service (Infinate Bus). Model 200 is used where the generator sets provide all the power for a site, or where they are switched to the facility loads with automatic transfer switches or interlocked breaker pairs. The control panel provides system monitoring and control functions using a software-based design concept. The control system provides flexibility to meet specific application requirements, ease of operator use, advanced functionality and optimum system reliability and serviceability. The Digital MasterControl may be integrated into the system power sections when required.

Fig. 4

Master Controllers MC150 for an automatic paralleling system.

Free standing motorised circuit breaker.

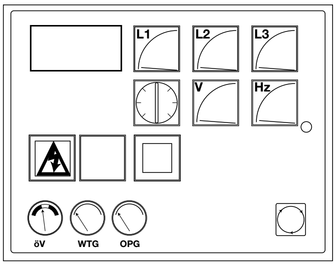


TYPICAL GENERATOR SET CONTROL AND ACCESSORY WIRING

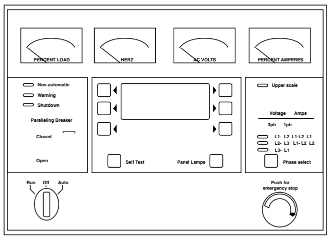
Fig. D1

Typical Automatic Mains Fail Application
PCL or PCC configuration

A single generating set with control system PCL002 or PCC, an automatic transfer switch and a transfer switch controller (the PCL005)

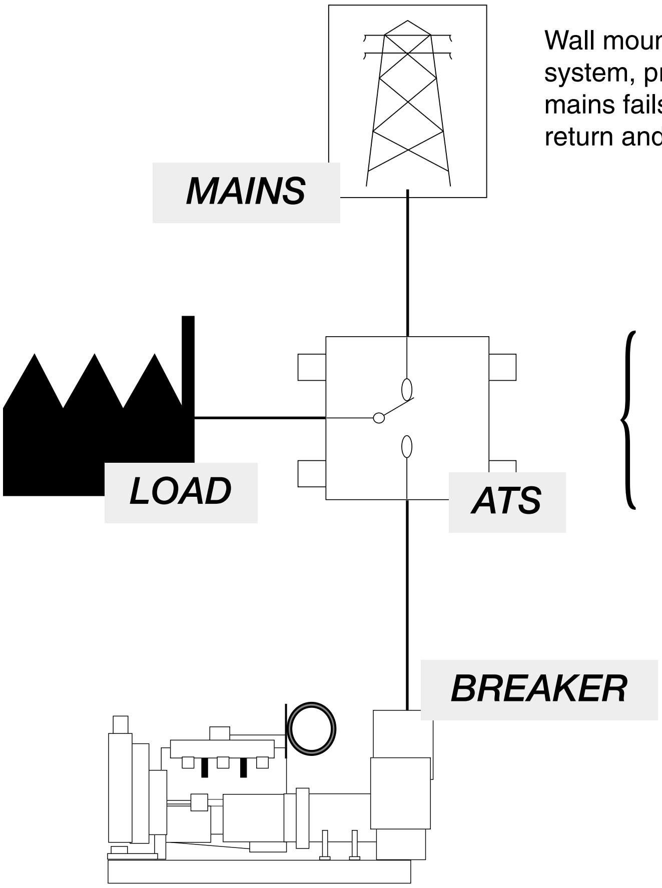


PCL002

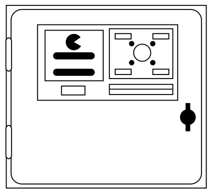


PCC (PowerCommand Control System)

PCL002 or PCC control system with two wire start input from the mains failure control unit PCL005



Wall mounting PCL005 mains failure control system, providing two wire start output when the mains fails. This incorporates mains fail, mains return and run on timers.



PCL005

Automatic Transfer Switch (ATS) wall mounting up to 1250 A and a free standing from 1600 A to 3200 A.

Parallel Operation

PowerCommand™ Digital Paralleling Systems are available for isolated prime power, emergency standby or interruptible applications utility (mains) paralleling applications. These systems are unique in that they use fully integrated, microprocessor-based control for all system control functions to eliminates the need for separate paralleling control devices such as synchronisers and load sharing controls.

PowerCommand™ Control allows state of the art servicing of the entire paralleling control system integration, monitoring and adjustment of system parameters with a laptop computer and InPower software tools.

The PowerCommand™ Control incorporates AmpSentry Protection for paralleling operations. This is a comprehensive power monitoring and control system integral to the PowerCommand™ Control that guards the electrical integrity of the alternator and power system from the effects of overcurrent, short circuit, over/under voltage, under frequency, overload, reverse power, loss of excitation, alternator phase rotation and paralleling circuit breaker failure to close. Current is regulated to 300% for both single phase and 3 phase faults when a short circuit condition is sensed.

If the generating set is operating for an extended period at a potentially damaging current level, an overcurrent alarm will sound to warn the operator of an impending problem before it causes a system failure. If an overcurrent condition persists for the time pre-programmed in the time/current characteristic for the alternator, the PMG excitation system is de-energised, avoiding alternator damage. The overcurrent protection is time delayed in accordance with the alternator thermal capacity. This allows current to flow until secondary fuses or circuit breakers operate, isolate the fault and thus achieve selective co-ordination.

Fixed over/under voltage and under frequency time delayed set points also provide a degree of protection for load equipment. Over/under voltage conditions trigger a shutdown message on the digital display screen and under frequency conditions prompt both warning and shutdown message, depending on the length of time and magnitude of variance below rated frequency.

AmpSentry protection includes an overload signal that can be used in conjunction with transfer switches or master controls to automatically shed load, preventing a potential generating set shutdown. The overload signal is programmable for operation at a specific kW level, on the basis of an under frequency condition, or both. It also includes protection for generating set reverse power, loss of excitation, alternator phase rotation and circuit breaker failure to close. It includes permissive (synchronising check functions for automatic and manual breaker closure operations.

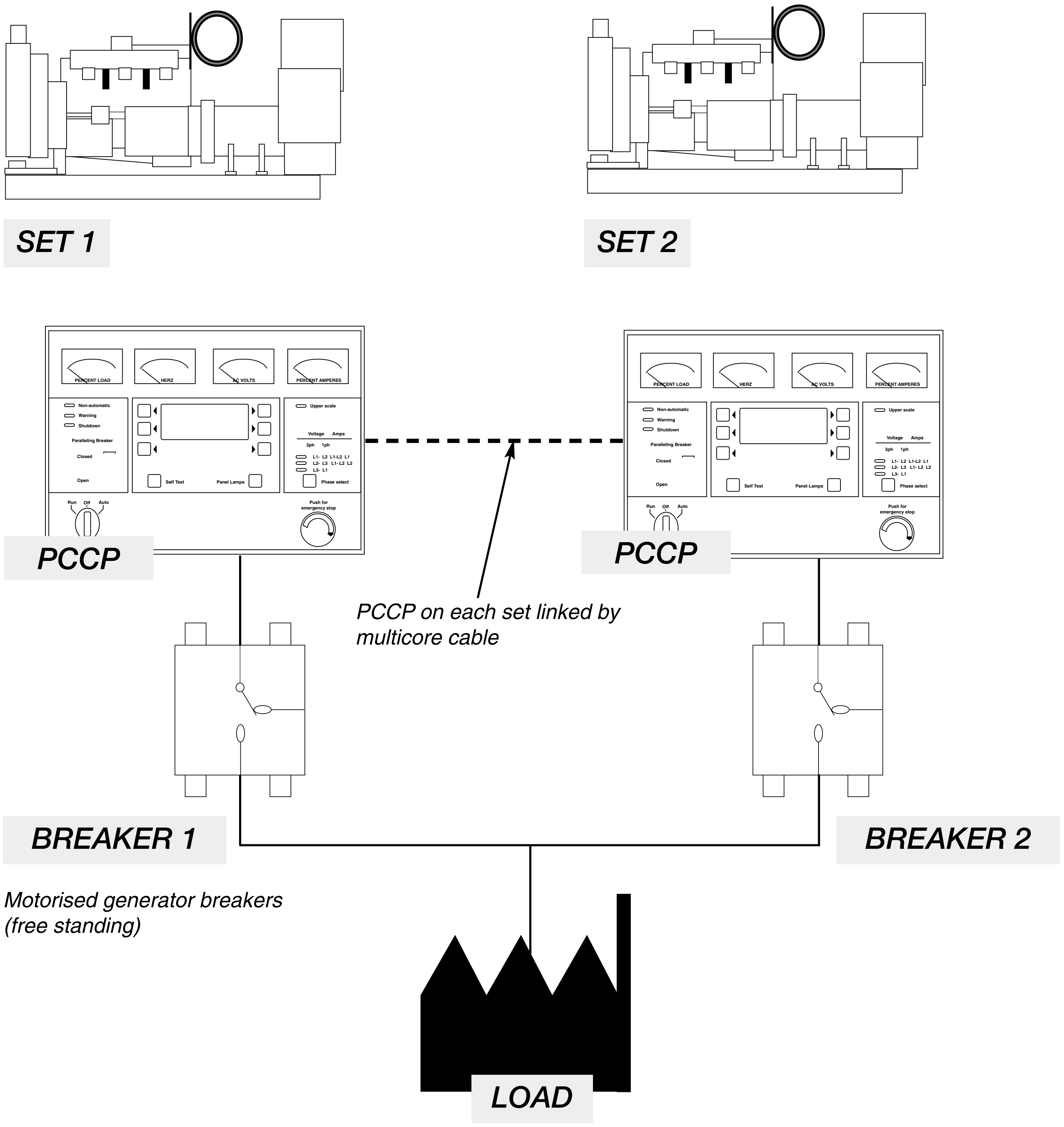
Seven 900 kVA sets working in parallel using the PCCP control system for a major soft drinks bottling factory in the Middle East.

Twelve 1250 kVA sets working together as construction camp base power using the PCL control system.

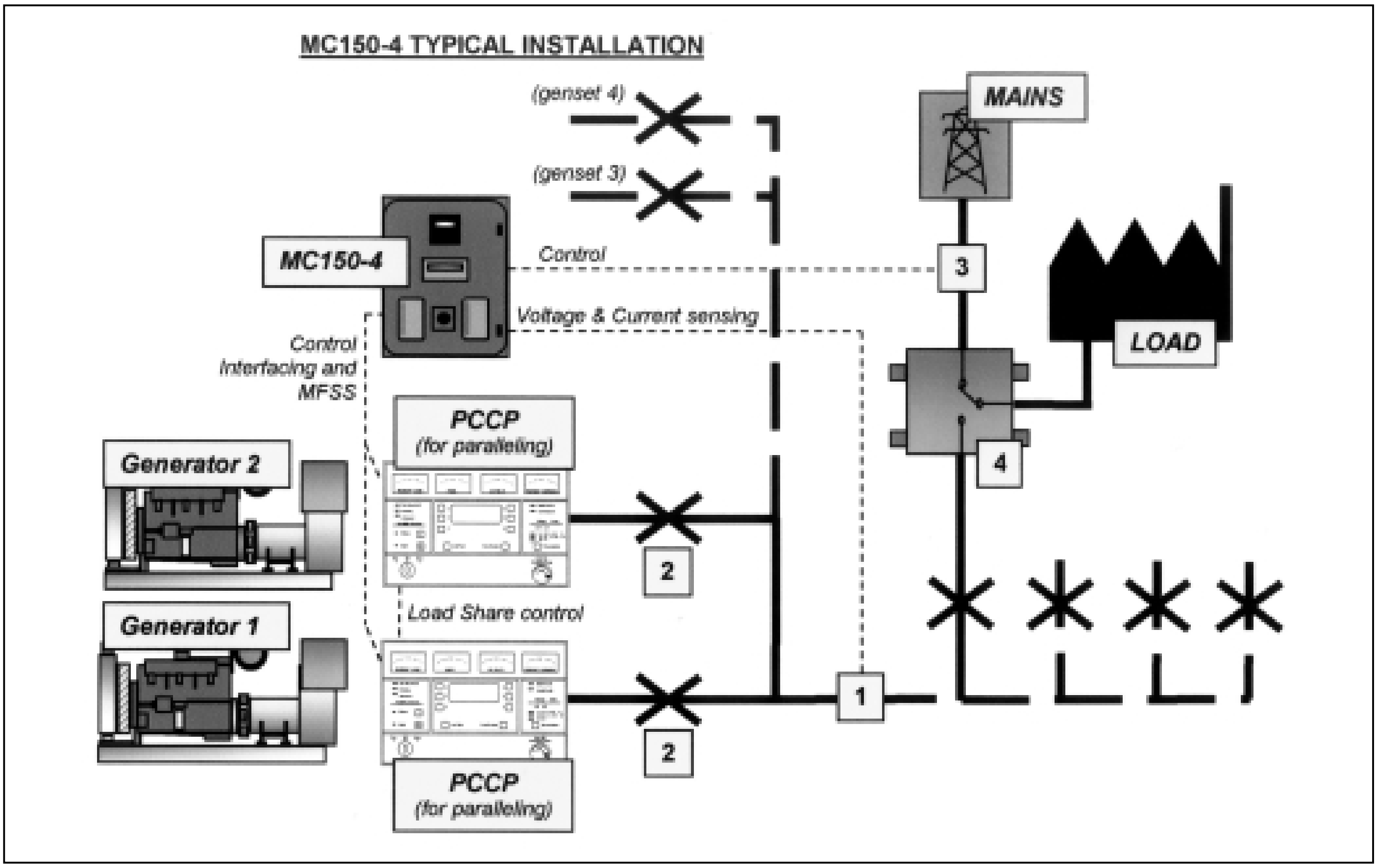
Thirty-nine 1125 kVA sets with KTA50 engines produce a combined 30MW of site power using PowerCommand Control (PCC) and Digital Master Control Systems when all operating in parallel.

Typical Paralleling Application
PCC configuration

An unlimited number of sets can be paralleled together with PCC(P). The PCCP requires a motorised breaker. Motorised breakers must be mounted in a free standing cubicle.



Two to Four set standby application with automatic synchronising



MC150-4 Features

The MC150-4 is a system controller designed to perform load related functions on an isolated bus system comprising two to four PCCP controlled generators connected via synchronising switchgear.

- **Contact start.**
- **Ready To Load Status Output.**
- **4 Stage Load Add/Shed Control.**
- **System restart.**
- **Digital multi-function metering for generator bus.**
- **Annunciator with status/fault LEDs.**
- **BMS interface (volt free signals).**
- **Manual Control.**
- **Wall mount or free-standing.**
- **Configurable for:**
  - Generator Demand Sequence and timing.
  - Load Add/Shed Sequence and timing.
  - Ready To Load status.
  - Individual generator ratings.
  - Number of generators (2-4).

Components Required:

1 Generator Common Bus Current Transformers to care of others (5A secondary*, class 1, 5VA nominal). Generator Common Bus Potential Transformers to care of other (if required).

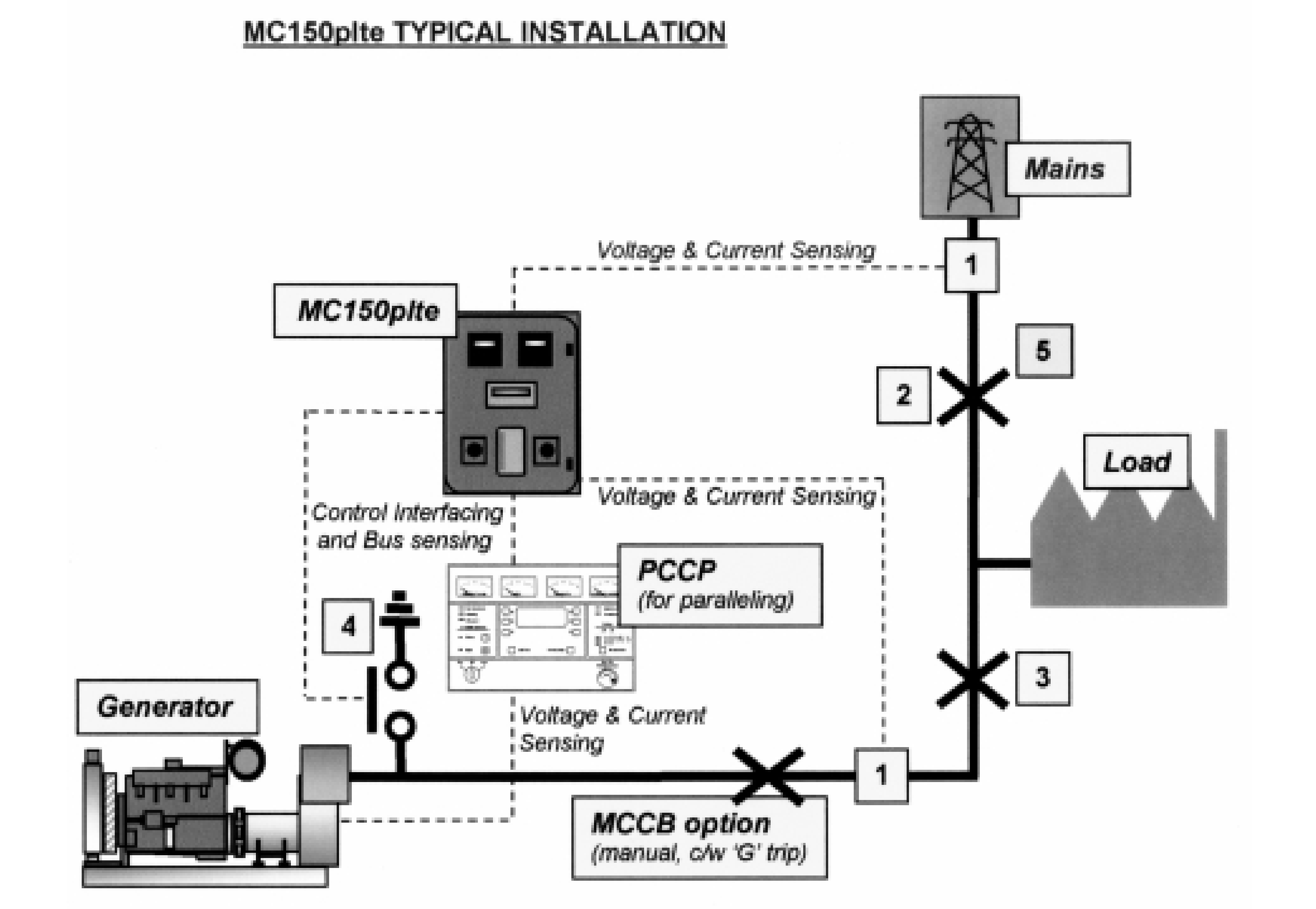
2 Generator Synchronising Switchgear (controlled by PCCP).

3 Mains Sensing (contact signal required by MC150-4 to start generators, ie: PCL005).

4 Changeover Switchgear (ie: ATS).

*Note: 1A secondary Current Transformers may be used to reduce the burden requirements for long cable runs.

Single set standby/peak lop application



MC150plte Features

The MC150plte is a system controller designed to operate as an Automatic Mains Failure system or a Utility Paralleling system for infinite bus applications involving one generator and one utility.

- **AMF operation with integral sensing, positive break and no-break mains return.**
- **Extended mains parallel operation for Peak Lop or Full Output (suitable for export).**
- **Run Off Load or Test On Load (transfer).**
- **G59 and Parallel Limit protection.**
- **Neutral Earth contactor control and monitoring.**
- **Digital multi-function metering for mains and generator.**
- **Annunciator with status/fault LEDs.**
- **BMS interface (volt free signals).**
- **Wall mount.**
- **Configurable for:**
  - AMF mains return modes.
  - Peak Lop modes (Auto, Manual and Share).

Components Required:

1 Mains and Generator Current Transformers to care of other (5A secondary*, class 1, 5VA nominal). Mains and Generator Potential Transformers to care of other (if required).

2 Mains Synchronising Switchgear (controlled by MC150plte).

3 Generator Synchronising Switchgear (controlled by PCCP).

4 Neutral Earth Contactor.

5 Mains Reverse Power (only if required by the application, ie: short term parallel protection).

*Note: 1A secondary Current Transformers may be used to reduce the burden requirements for long cable runs.

Networking

The PowerCommand™ Control includes a Generator Control Module (GCM) which allows for communications over the PowerCommand™ Network. The Network is suitable for local or remote control and monitoring using PowerCommand™ Network hardware and PowerCommand™ software for Windows“. See Fig. 28.

The Network provides complete and consistent control, monitoring and information access, additionally, all alarm events may be programmed to automatically dial out to a user specified telephone number upon alarm occurrence. This provides all the required information, when needed, from unattended sites. All events including alarms, operator activities and system events are recorded and may be printed as reports or saved to disk for archiving purposes.

PowerCommand™ software for windows allows the facility for remote monitoring of the generation sites. A Remote Access, Single Site version of Power Command will be provided for a host monitoring computer. Power Command will provide detailed information on the status of the generating sets and their associated accessories.

The system communicates using an unshielded twisted wire pair which eliminates the need for expensive hardwired, point to point terminations.

AC Terminal Box

The AC terminal box, which forms part of the GCP (Generator Control Panel), acts as marshalling box between the engine / alternator and the AC auxiliary supplies / control panel monitoring system.

Alternator Terminal Box

The alternator output terminals are mounted on a flat thick steel saddle welded on the non-drive end of the alternator. The terminals are fully sealed from the airflow and are widely spaced to ensure adequate electrical clearances. A large steel terminal box is mounted on top of the saddle. It provides ample space for customer wiring and gland arrangements and has removable panels for easy access. Contained within the Alternator terminal box is the following instruments and controls:-

- Current Transformers
- Alternator Voltage Regulator module
- Electronic Governor module

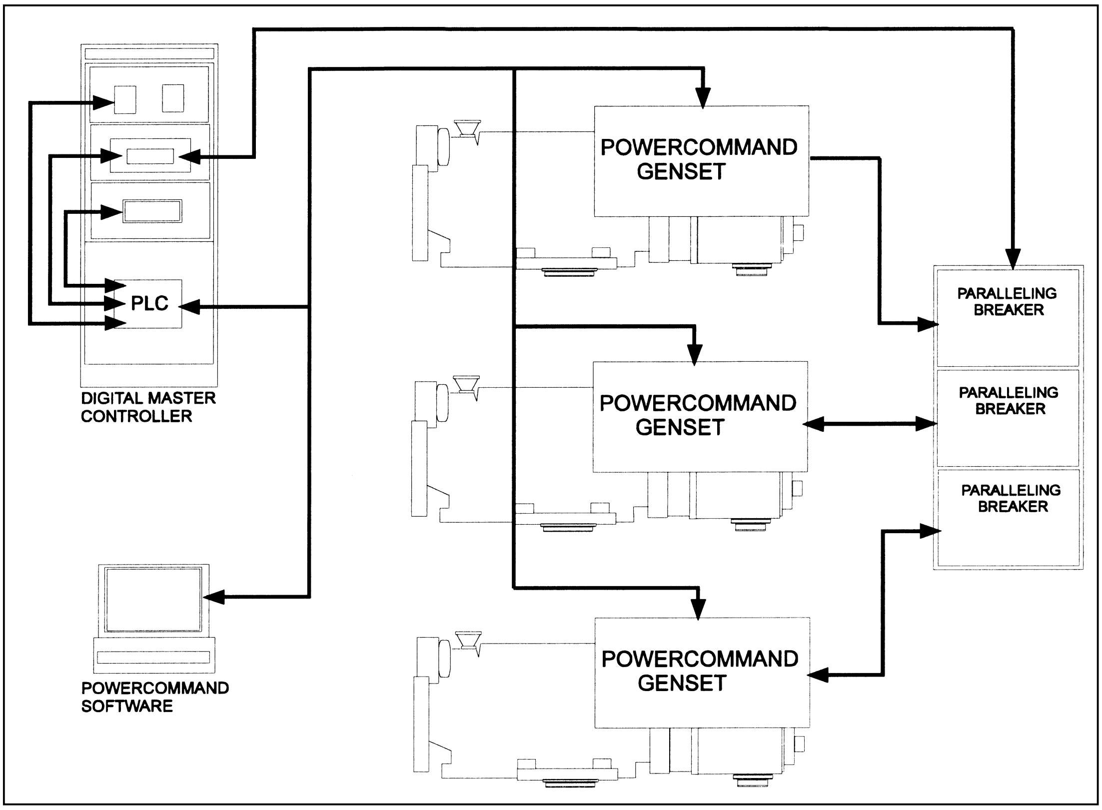


Fig. D2 PowerCommand™ Network

A circuit breaker is an electro-mechanical switch which can be connected in series with the alternator output. The breaker is a type of automatic switching mechanism. Under normal circumstances, it passes current and is said to be closed. It automatically “opens” or “trips” and breaks the circuit when excess current over a preset level flows. The **RATING** of a breaker is the thermal full load capacity of the breaker which it can pass continuously. The essential purpose of a generator circuit breaker is to:

PROTECT THE ALTERNATOR AGAINST EXCESSIVE CURRENT BEING DRAWN WHICH WOULD EVENTUALLY OVERHEAT THE INSULATION AND SHORTEN THE LIFE OF THE MACHINE.

Excessive current would flow as a result of either:

PHASE TO NEUTRAL SHORT CIRCUIT

or

PHASE TO PHASE SHORT CIRCUIT

A circuit breaker should ensure that current levels detailed in the damage curves for the alternator do not flow for longer than the times specified in the damage curves.

Circuit breakers are classified by their trip rating and number of poles.

Breakers provide one trip system per phase and an option for a neutral conductor trip, all are mechanically interlocked, i.e.

- **3 POLE** – all three phases
- **4 POLE** – all three phases and neutral.

In addition, a main line breaker serves the following purposes:

- **DIFFERENTIATE BETWEEN SUSTAINED AND TEMPORARY SHORT CIRCUIT CONDITIONS, TRIP IN THE PRESENCE OF A SUSTAINED FAULT AND NOT TRIP IN THE PRESENCE OF A TEMPORARY FAULT, WHICH CAN BE CLEARED BY THE DOWNSTREAM DEVICES.**
- **PROTECT THE ALTERNATOR FEEDER CABLES IN THE EVENT OF EXCESSIVE CURRENT FLOW.**
- **PROVIDE A MEANS OF ISOLATING THE ALTERNATOR FROM EXTERNAL EQUIPMENT (BY AUTOMATIC AND MANUAL MEANS).**

When generators are connected in parallel, breakers are essential for isolating one running generating set from another which may not be running. Without the ability to isolate the set which is not running, the running set would motor the non-running set. This would result in damage to the engine, and/or alternator on that set.

CIRCUIT BREAKER SYMBOLS

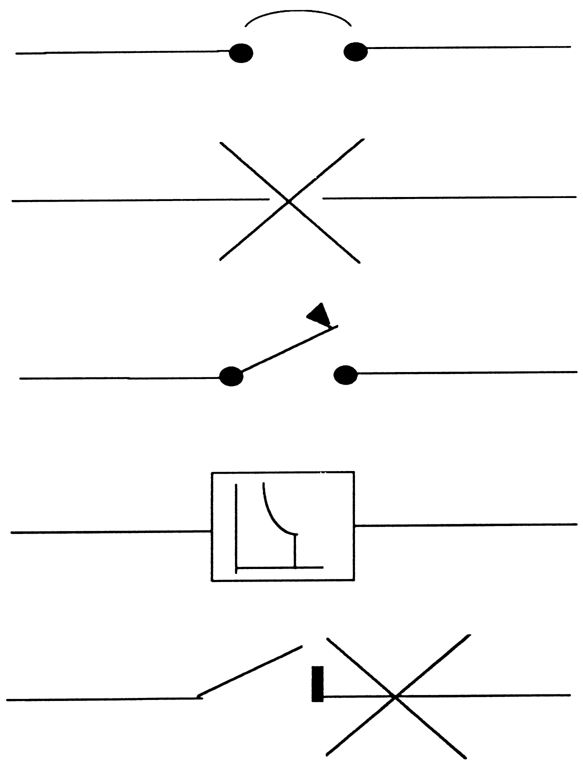
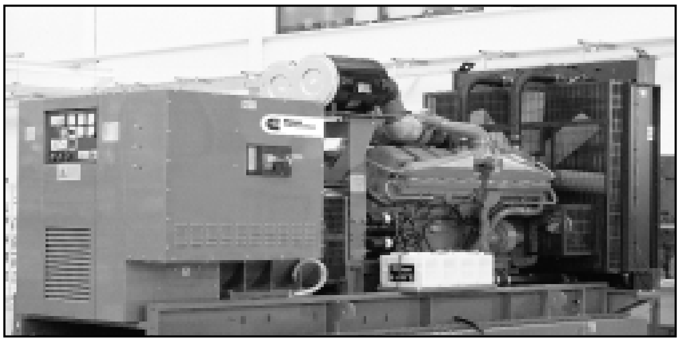


Fig. D7 In practice, many different symbols are used to represent a circuit breaker by different manufacturers.



Typical set mounted circuit breaker up to 700 amperes.

Set mounted 1000 ampere circuit breaker.

Fault Clearance Time

This is the time taken for the protective device, the breaker, to disconnect the generator set from the load in the presence of a fault. Different levels of fault current require different disconnection times. For example, an alternator can sustain an overload current of 120% for far longer than it can sustain 300%, without degradation to its insulation.

Local legislation dictates the required maximum clearance time of protective devices under short circuit or earth fault conditions. In practice this is dependent on:

- **THE EARTH LOOP IMPEDANCE OF THE INSTALLATION**
  This is determined by calculation of the resistance of all conductors in the system, or by measurement.
- **THE SENSITIVITY OF THE PROTECTION DEVICE**
  Magnetic trips found in MCCBs can be adjusted to within a tolerance of 20%, while solid state breakers can be adjusted to within 1%.

Circuit Breaker Action

The action of breaking a current flow between two contacts of a circuit breaker causes the air between the contacts to ionize and conduct, the result being an arc across the contacts.

Contact arcing is undesirable, several methods of increasing the resistance, and therefore dissipating arcs, are employed in circuit breakers. Increasing the resistance of the medium between the contacts is the prime method of arc reduction used. This breaker medium is also used loosely by breaker manufacturers to classify breaker types.

The term **FRAME** used in relation to breakers is used to describe the physical size of the mechanical housing used to contain the circuit breaking mechanism.

- **ACB – Air Circuit Breaker**
  Air is used as the arc interrupt medium, ACBs are loosely divided into:

  MCCB – Moulded Case Circuit Breakers
  These are light duty, sealed, and relatively inexpensive breakers. Current technology provides MCCBs for operation up to 690V and between 100 to 2500A. Note Miniature Circuit Breakers MCBs are available from 2-100A as single phase units. These are for use in distribution systems, MCBs are very light duty units for down-line load protection, where fuses might also be used.

High Voltage Circuit Breakers

- **Oil Circuit Breakers**
  Oil filled breakers have now largely been superseded by advances in VCBs. Oil is used as the interrupt medium. The oil has to be changed at periodic intervals and presents a danger in certain installations.
- **VCB – Vacuum Circuit Breakers**
  The insulation properties of a vacuum make it an excellent arc quencher for HV applications.
- **SF6 – Sulphur Hexafluoride Breakers**
  When pressurised, SF6 is an excellent insulator and braking medium for HV applications.

NB: SF6 has toxic by-products.

Moulded Case Circuit Breaker (MCCB)

MCCBs are in common use for protecting low voltage generating sets, they are available is sizes of 100A to 2500A. The moulded case of the circuit breaker is sealed and maintenance free. The MCCB is designed to be an inexpensive protection device and as such is not intended for repeatedly interrupting fault current (20000 to 50000 changeover cycles). As fault current only flows as the exception and not the normal in a generating set application, MCCBs are acceptable for use on the most common generating set applications up to approximately 1000A, above which ACBs are more often used.

MCCB Action

MCCBs detect and clear faults by thermal and magnetic trip action.

- **Magnetic Action**

  Purpose
  The magnetic tripping element's characteristic is to give an instantaneous trip in the case of an extreme short circuit, which would damage the alternator.

  Construction
  The magnetic tripping element is a type of electromagnetic solenoid operating from the breaker current.

Trip Time
There is **NO INTENDED** time delay in this trip, though the physical breaking action takes about 16ms.

Adjustment
Adjustment is provided on the instantaneous trip level, the range of adjustment varies according to the manufacturer, but 2-5 times trip rating is possible for a 'G' trip, 4-10 times for a 'D' trip.

- **Thermal Action**

Purpose
The thermal tripping element's characteristic is to give inverse time delayed tripping action in the case of long-term over current which, if allowed to continue, would damage the alternator.

Construction
The thermal trip is a bi-metallic strip, arranged to deform with the heating effects of long-term over current.

Trip Time
The trip time is not instantaneous, it is proportional to the time and level of current flowing over the breaker rating.

Adjustment
Thermal trips are calibrated by the manufacturers of the breaker, a 40%-100% adjustment range is typically provided. Thermal trips are often provided as interchangeable modules which will fit a range of physically different frame sizes.

In addition, MCCBs are designed to incorporate the following features:

- **Manual Trip Action**

Purpose
To provide a means of manually isolating the alternator supply. Used in testing the generator set and as a crude switch in some basic applications.

Construction
A toggle is provided which is normally arranged to protrude from the breaker housing. This can be operated like a switch to open the breaker. However, should the toggle be physically held closed in the presence of over current, the breaker will still trip.

Trip Time
Regardless of the speed of manual operation, the trip is arranged to always switch in a fixed time period, i.e. that of the instantaneous magnetic trip.

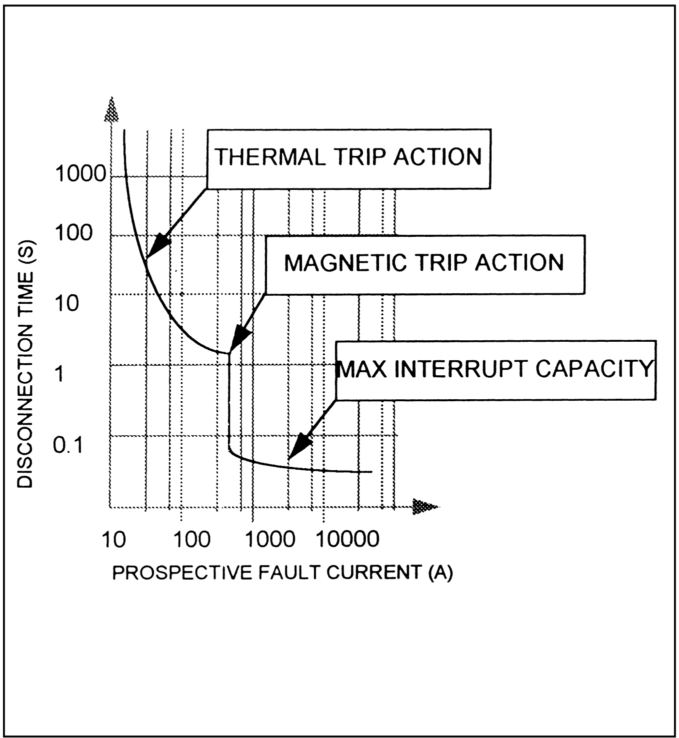


Fig. D8 MCCB THERMAL AND MAGNETIC TRIP PROFILE

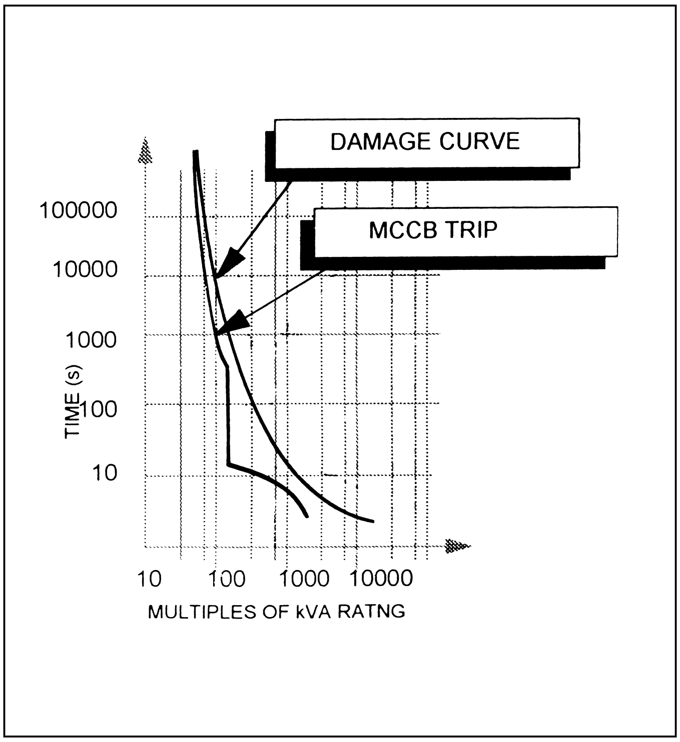


Fig. D9 MCCB TRIP PROFILE AND THE ALTERNATOR DAMAGE CURVE

- **Motor Operated Breaker For Paralleling**

  Purpose

  A motor assembly (typically DC) is provided by the breaker manufacturer. This motor assembly fits neatly onto the breaker assembly. It provides a means of opening and closing the breaker from a switched motor breaker supply under controlled conditions (unlike the shunt trip, which is provided to open the breaker in the case of a fault). The motor breaker supply may be switched through paralleling equipment, the motor breaker is an essential feature of any automatic paralleling system. It must be capable of closing the circuit breaker within 250 msec.

  Construction

  Motors for MCCBs fit either to the front or side of the breaker. The complete unit is larger than a single MCCB and housings designed for manual MCCBs often require modification or alternative hood arrangement to house a motor MCCB.

Breaker Capacity

Most standard specification generating sets are supplied with a breaker as part of the package. In these circumstances, the breaker will suit the majority of generator set applications and will usually be sized around the standby rating.

When selecting a breaker, the following should be considered:

Steady Current Carrying Capacity

This is the continuous current which the breaker will carry during steady state conditions. For example, while the generator is running at full load.

Breaking Capacity

This is the maximum current rating which the breaker is able to operate. For example, this would be in the order of 40 times the rated carrying capacity (the level at which the magnetic trip will operate). The breaking capacity required should be calculated from the worst case three phase fault current of the load circuit.

Ambient Temperature

Breakers are usually rated for 40ºC before derate. As the tripping action relies on thermal action it is extremely important to consider the ambient environment and the effect of the enclosure on breaker operating temperature.

Continuous Operation

The breaker should carry its full load rating indefinitely.

Full Load Current

Full load current or FLC can be calculated for a given system from:

$$\text{FLC} = \frac{1000(\text{POWER in kW}) \times \text{POWER FACTOR (Gen)}}{1.73 \times \text{PHASE VOLTAGE} \times \text{POWER FACTOR (load)}}$$

or

$$\text{FLC} = \frac{1000(\text{APPARENT POWER in kVA})}{1.73 \times \text{PHASE VOLTAGE}}$$

MCCB Physical Size, Mounting and Connection

Circuit breakers increase in physical size with the increased current carrying and tripping capacity. With current technology, MCCBs are available up to 1000A and can be mounted onto the alternator conduit box. This is done for reasons of economy. Vibration rarely causes a problem, however towards 630A, it is common to find the breaker separately mounted from the alternator for added vibration isolation.

Above 1000A the breaker would be of the traditional ACB type, larger and heavier than an MCCB. This type of breaker would be mounted in a free-standing cubicle.

As the current carrying capacity of the breaker increases, so does the load cable diameter. It is common practice to double up on load cables, that is use two per phase, instead of using one large, and often very expensive area on the breaker terminal required for the load cable lugs to be fitted. In addition, the glanding and channeling arrangement for the load cable will increase as the number of load cables are increased.

It is necessary to obtain some idea of customer load cable arrangements, as this will figure in deciding upon the most appropriate position for the set breaker and the trip settings.

The use of steel wire armoured cables will necessitate the use of an interposing link box between a set mounted breaker and the armoured load cable. Armoured load cable is rigid and should be installed into a trench or into fixed channeling. This type of cable should be terminated close to the generator set and flexible cables used to connect to a breaker which is vibration isolated from the bed of the set. Failure to use this arrangement for steel wire armoured cable will almost certainly result in the disturbance of the cable mountings on the generating set with eventual damage to the load cable and possible fire.

For specific details on the type and specification of the breakers consult Cummins Power Generation.

Low Voltage System Breakers

The L.V air circuit breakers are compliant with International Standards, they are safe and reliable and have a range of control units which offer multiple functions, accessories and auxiliaries to suit the site requirements. Circuit breakers are operated via a stored energy mechanism for instantaneous opening and closing. The mechanism is charged either manually or electrically as required.

All characteristics for the breaker operation should be collated, so that selection of the required breaker can be made from the Merlin Gerin Manual. The points to be considered are:-

- rated current and voltage
- number of poles required, either three or four depending on the application of the system.
- breaking capacities and protection type

Auxiliaries and accessories

The manufacturer's literature should be consulted for the short circuit curves and technical data before selection of the breaker can take place.

Medium and High Voltage System Breakers

The circuit breakers are compliant with international Standards and designed for a range of voltages up to 24kV and symmetrical breaking fault levels up to 40kA. The insulation and arc control systems are designed and certified for use on 3 phase 50/60Hz systems with earthed neutral. The manufacturer must be consulted if this type of breaker is required to be used on any other application.

Facilities fitted on the Circuit Breaker include:-

- A spring closing mechanism is fitted that may either be charged by hand or by means of a spring charging motor and the breaker may be tripped by means of a mechanical trip lever or by the trip coil.
- Interlocks are incorporated into the design to prevent potentially dangerous situations or operations, also control levers can be supplied with padlocking facilities.
- A cast resin insulation system enables an optional 125kV impulse level to be incorporated into the unit for current 12kV systems, complete with a monobloc moulding which houses three contact systems and carries the main isolating contacts with insulators, shrouds and busbar receptacles.

The manufacturer's literature should be consulted for the short circuit curves and technical data.

Contactors

Contactors can be supplied if required, for automatic changeover between the mains supply and the generator output supply. The contactors are fitted in a separate switchgear panel, complete with electrical and mechanical interlocks. They can be supplied as three or four pole depending on the application and neutral earthing of the system with instantaneous overload protection.

The manufacturers' literature should be consulted with regards to the short circuit curves and technical data.

It is essential that contactors are backed up by suitable fault interrupting devices such as circuit breakers or fuses.

Busbar Arrangements

Where one or more single busbar system output breaker panels are fitted together, the linking or commoning of the supplies or outputs is achieved by the use of a single busbar system.

Stationary breakers and buswork are housed within a rigid, free standing panel, designed for indoor applications, provided with bolt on covers, barriers and supports. The framework is constructed with a minimum of 12 gauge steel metal. Control components are totally isolated from power carrying components by metal or insulating barriers. All components and surfaces operating in excess of 50 volts are shielded to prevent inadvertent contact.

The current carrying capacity of busbars is determined by the materials conductivity and the operating temperature. In an air insulated system heat is dissipated from the busbars, however where the bars are insulated the heat convected away is very small.

The busbar must be rated in accordance with its installation requirements.

Note: Where customer-supplied switchgear is used for generators paralleling, ensure that the total closing time is less than 250 msec.

Breaker Enclosures

Breaker enclosures are provided to protect live terminals from the touch of operators, to contain electrical arcs and to protect from the effect of the environment.

The housing of a breaker for generating set protection is normally either set-mounted, wall-mounted or free-standing. The wall-mounted and free-standing types require interconnection cable between alternator and breaker, which will be physically further away than the set-mounted devices. This physical distance should be kept as short as possible and the interconnecting cables should be rated with the breaker capacity in mind.

The affect of the enclosure on the breaker rating should be carefully considered. The thermal tripping capacity of a breaker must be derated with increase in ambient temperature. It therefore follows that the better the sealing of a breaker enclosure, and hence the worse the ventilation, then the more the breaker will require derating.

This derate should be incorporated into the generator set design. However when operating at full load capacity in high ambient temperatures (above 40°C), it is important to consider the effect of the increased ambient to avoid nuisance tripping of the breaker or overheating of the internal conductors.

The degree of protection provided by a breaker enclosure is classified by the Index of Protection (IP) as outlined by BS 5420 (IEC144).

As a general guide, IP33 is a standard specification for indoor breaker enclosures, this offers protection:

- against the ingress of foreign bodies up to 2.5mm diameter
- against contact by the fingers with internal parts
- against vertically falling water droplets.

As a general guide, IP55 is an enhanced specification for indoor breaker enclosures, this offers increased protection:

- against harmful ingress which would prevent normal operation
- against contact by the fingers with internal parts
- against jets of water from any direction.

Discrimination and Coordination

In electrical distribution systems with one large feeder (a generator set) feeding multiply branches, it is important to insure that a single fault on one small load of a few amps on one branch, does not cause the whole system to shut down. Particularly in stand-by generating set systems, where critical loads must be maintained, the breakers and fuse systems must be arranged to isolate a faulty load and allow the rest of the circuit to operate undisturbed.

The term **DISCRIMINATION** (or selective tripping) applied to electrical systems is used to describe a system with graded protective devices which operate to isolate only the faulted load from the rest of the circuit.

The term **CO-ORDINATION** applied to electrical systems is used to describe the arrangement of discriminative tripping devices.

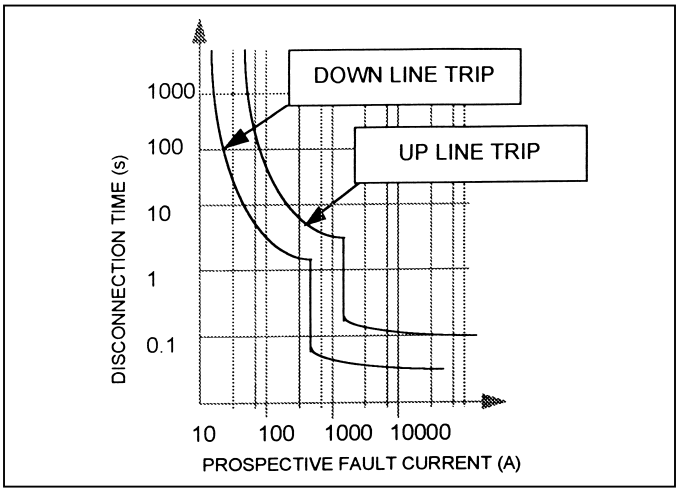


Fig. D10

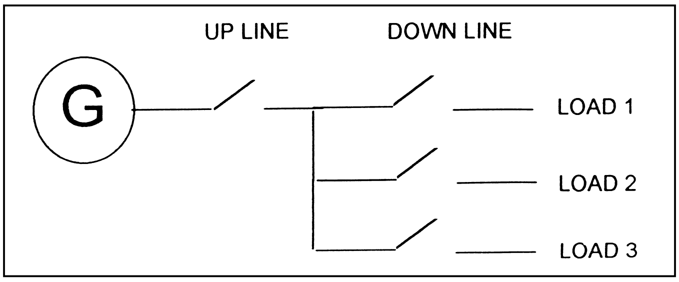


Fig. D11

Breaker Checklist

- **LOAD FAULT CURRENT VERSUS BREAKER CONTINUOUS LOAD CURRENT RATING**
- **FAULT CLEARANCE TIME**
- **DERATE FOR TEMPERATURE**
- **SPECIFY NUMBER OF POLES**
- **SET-MOUNTED OR FREE-STANDING ENCLOSURE**
- **IP RATING OF ENCLOSURE**
- **SYNCHRONISING MOTOR MECHANISM**
- **NUMBER OF CUSTOMER LOAD CABLES PER PHASE AND CABLE LUG SIZE**
- **STEEL WIRE ARMOUR CABLE TERMINATION ARRANGEMENTS**
- **GLANDING AREA REQUIRED FOR CUSTOMER LOAD CABLES**
- **BENDING RADIUS OF CUSTOMER LOAD CABLES ONTO BREAKER**

Automatic Transfer Switch (ATS)

The term **ATS** or **AUTOMATIC MAINS FAILURE PANEL** is usually associated with the switching arrangements for mains fail emergency standby generating set systems. The purpose of an automatic transfer switch is to:

- **MONITOR THE UTILITY SUPPLY FOR FAILURE**
- **TRANSFER THE LOAD TO AND FROM THE UTILITY SUPPLY TO THE STAND-BY SYSTEM IN A CONTROLLED MANNER**

The ATS contains a power switch element and a control element. The control element is sometimes part of the generator set control or some centralized control system in larger installations.

The ATS is usually housed in a separate cubicle wall-mounted or free-standing. The ATS may be located in the main switching facility of a large installation, whereas the generator may have its own dedicated building. It is most desirable to site the ATS near to the load, thereby minimising the length of cable run from each power source to the load.

Automatic Transfer Switch Control System

In some European specifications, the transfer switch controls can be located on the generating set, others will have a degree of intelligence (timers) built into the transfer switch. The transfer switch control system is responsible for the following three control sequences.

Mains Fail

In order to detect the failure of the utility supply the control system must compare the utility supply voltage with a preset minimum or maximum level, then a timer is started. The timer introduces a delay of about 5 seconds before the transfer switch will start the generating set. The purpose of this **MAINS FAIL TIMER** is to ensure that short duration dips in the utility supply voltage will not cause the generator to start unnecessarily. As a result of the mains fail timer expiring, the controller signals the generator to start. The generator control system activates the starter motor. This will engage and rest the starter motor for regular periods until the engine turning conditions are detected. (Alternator voltage, speed sensed at the flywheel.) If the engine does not start after a pre-determined number of attempts, then a fail to start alarm is indicated.

Once the generator is up to rated frequency and voltage the changeover to the generator supply occurs.

Mains Return

Once the generator is running and supplying the load acting as emergency standby, the utility supply may be reinstated. There may, though, be several cases of the utility supply being established momentarily and then failing again. The **MAINS RETURN TIMER** takes care of this effect by starting every time the mains is established and resetting should the mains drop off again. The mains return timer is usually around 3 to 5 minutes, the mains must therefore be healthy for this period before the transfer switch changes over the supply source.

Run On

After the transfer switch has re-connected the load onto the mains, the generator set is **RUN ON** for a cooling down period (typically 5 minutes) before it is signalled to stop by the transfer switch. Should the mains fail again during this **RUN ON** period, then the transfer switch will immediately switch in the generator set output.

In addition, it is common to site the engine exercising timer in with the ATS control system in automatic mains failure stand-by systems.

Exercise Timer

This will automatically start the generator set at regular periodic intervals. The transfer switch is not changed over from the utility supply position when the generator is automatically exercised.

It is important to be clear on the most suitable position for the transfer switch controls in any application. This may be dictated to a large extent by the features of the particular genset/ATS controls used.

In cases where the generating set is located near to the ATS and the generating set batteries are available, these can be used to power the ATS.

In cases where the ATS is to be located remotely, some distance (more than 20 metres) from a generating set, it is not recommended to run long lengths of supply cable to the ATS, as the volt drop in these cables can lead to control problems. A relay scheme will assist in these cases.

The battery charger should be positioned as close to the generator as possible to avoid voltage drop in the DC wiring.

ATS Standards

ATS units should meet any local legislation and the international standards. As standard products, they are available in approved ratings from 30A to 4000A below 600V.

For use in North America, ATS should be UL approved. ATS are listed in Underwriters Laboratory Standard UL1008. UIL approval adds to the cost of the ATS and is not necessary for the sale of an ATS in Europe.

ATS Power Switch Element

Transfer switches are available as three or four poles switching mechanisms (linear switches) and changeover contactor pairs. They employ similar techniques to current breaking as circuit breakers. Many ATS systems under 1250A are comprised of two contactors mechanically and electrically interlocked. Above 1250A, it becomes economic to substitute circuit breaker element for the generator contactor.

Sizing an ATS

To correctly detail the transfer switch requirement for a particular application, it is necessary to consider each of the following features of an ATS.

Voltage

The operating voltage of the ATS must be greater than the circuit voltage.

Frequency

The operating frequency of the ATS must be equal to the operating frequency of the circuit.

Number of Phases

In general, transfer switches are available as three phase units, in either three or four pole configurations.

Number of Cables Per Phase

Each phase may comprise of more than one cable to carry total load. It is important to ensure that there is adequate termination on the transfer switch for the number of cables used to carry the load. For example, there may be two cables per phase onto the switching mechanism. The width of the termination lug and the diameter of terminating bolt need to be known in order to determine the cable termination arrangements. Most manufacturers offer a range of termination kits which can be retro fitted onto a standard terminal arrangement. Always follow manufacturer's and code recommendations for cable termination. There are minimum safe distances between exposed conductors.

Type of Load

Special consideration must be given to switching motor loads. For example:

- **MOTORS**
- **HIGH INERTIA LOADS**
- **CENTRIFUGAL PUMPS**
- **CHILLERS**

Due to the voltage decay characteristics of inductors when experiencing a sudden change to the current flow, the voltage across motor terminals will take time to fall. For this reason, it is necessary to incorporate a delay into the transfer action of the ATS when live switching motors, known as "dead time", (typically 1-2 sec). This is usually provided as a timer in the ATS control, which is normally set to instantaneous transfer with no motor loads.

Available Fault Current

Unless the transfer elements are circuit breakers the ATS must always be protected by a fault breaking device.

Number of Switched Poles

Ground fault protection of electrical systems that have more than one power source, i.e. a load is fed by either a utility or engine generator set, requires special consideration. A problem may occur in that the neutral conductor of the engine generator set is generally required to be grounded at its location, thus creating multiple neutral-to-ground connections. Unless the system is properly designed, multiple neutral-to-ground connections may cause improper sensing of the ground fault currents and nuisance tripping of the circuit breaker. One approach is to use a four pole ATS in which the neutral conductor is switched to provide isolation in the event of a ground fault.

Cable Entry

As the rating increases, the routing of cable becomes increasingly more awkward. It is important to specify the correct cable entry point into the ATS enclosure for the type of cable, its angle of entry to, and connection point within, the enclosure.

Temperature

The continuous rating of an ATS will be quoted up to 40^{o}C approximately, above this a derate must be applied to the maximum current carrying capacity.

ATS Checklist

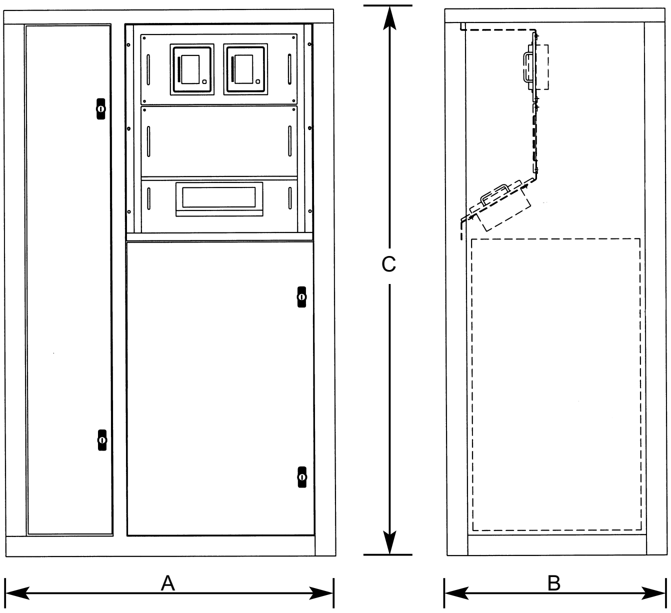
- **VOLTAGE**
- **FREQUENCY**
- **NUMBER OF PHASES**
- **NUMBER OF CUSTOMER LOAD CABLES PER PHASE**
- **LOCATION OF ATS MAINS FAIL DETECTION AND CONTROL TIMERS**
- **SUPPLY VOLTAGE FOR ATS CONTROL**
- **INDUCTIVE LOAD SWITCHING – TRANSITION TIMERS**
- **LOAD FAULT CURRENT VERSUS CONTINUOUS ATS/CONTACTOR PAIR CURRENT RATING**
- **NUMBER OF SWITCHED POLES**
- **DERATE FOR TEMPERATURE**
- **IP RATING OF ENCLOSURE**
- **NUMBER OF CUSTOMER LOAD CABLES PER PHASE AND CABLE LUG SIZE**
- **STEEL WIRE ARMOUR CABLE TERMINATION ARRANGEMENTS**
- **GLANDING AREA REQUIRED FOR CUSTOMER LOAD CABLES**
- **BENDING RADIUS OF CUSTOMER LOAD CABLES ONTO BREAKER**

ATS – Wall mounted version

ATS – Floor mounted version.

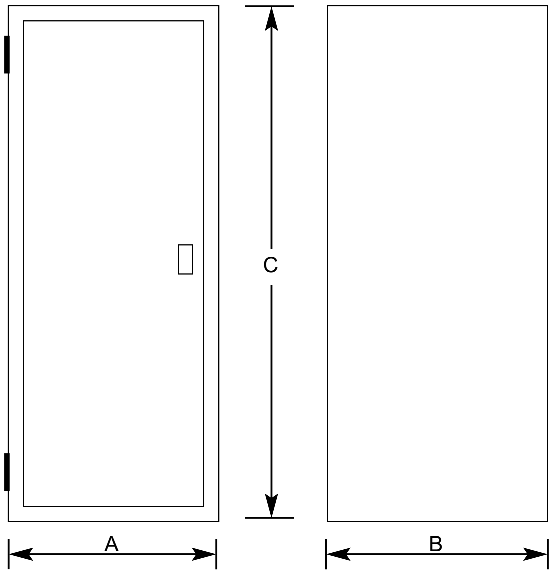
Terminal box on Control Panel for transfering output to floor mounted auto transfer cubicle for a 625 kVA set.

DMC – Digital Master Control



DMC mm		
A	B	C
1400	800	2000

Circuit Breaker

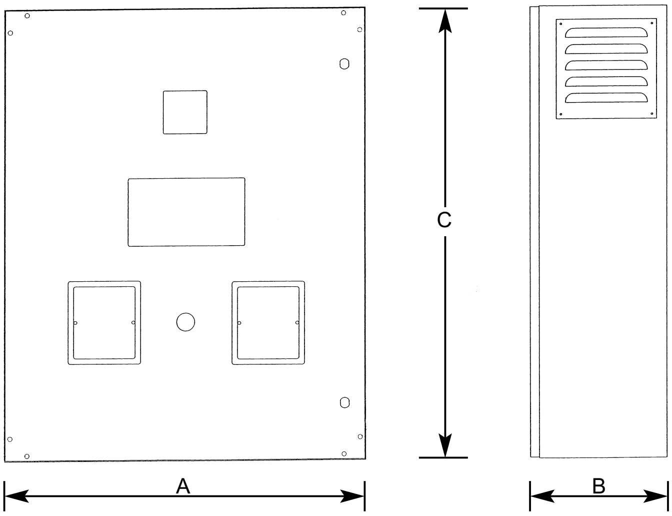


Floor mounted circuit breaker and load terminal cubicle			
Capacity	mm		
A	A	B	C
1600	1000	1050	1500
2000	1000	1050	1500
2500	1000	1050	1500
3200	1000	1050	1500
4000	Refer to factory		

Note:– Provision for access to the rear of most cubicles is generally unnecessary as components can be accessed from the front.

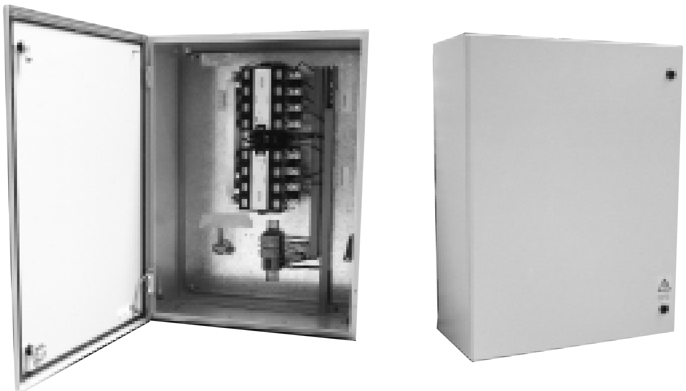
Power and control interconnections can generally be made either from the top or bottom of the enclosure (consult your project drawings for exact details on this point).

MC150-4
MC150-PTE

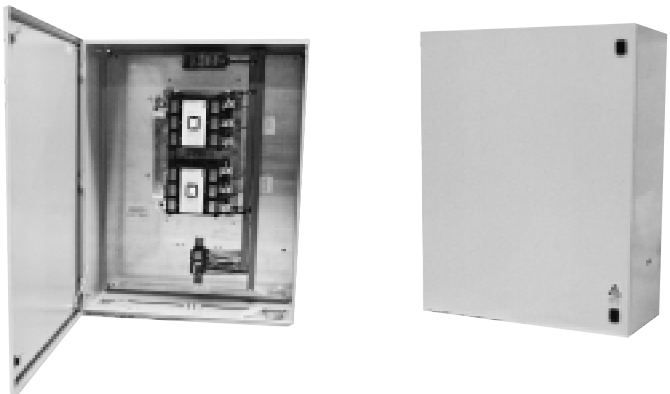


Master Controller Wall Mounted		
A	B	C
800	1000	300
Floor Mounted Version		
800	600	2000

CHANGEOVER CONTACTOR CUBICLES



Wall mounted c/o contactors 125 amp.



Wall mounted c/o contactors 500 amp.

Floor mounted c/o contactors 1000 amp.

Floor mounted c/o cubicles
up to 2500 amperes.

CHANGEOVER CONTACTOR CUBICLES

Wall mounted cubicles up to 700 amperes

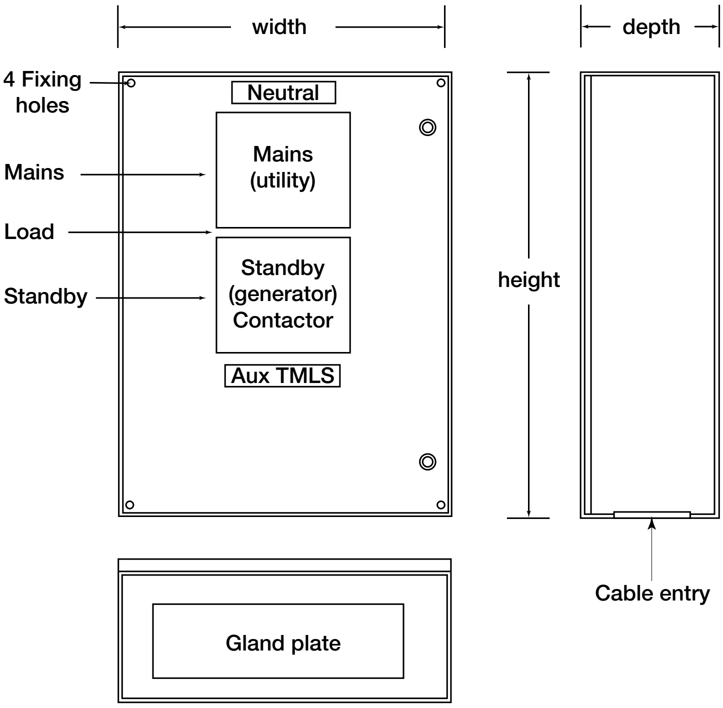
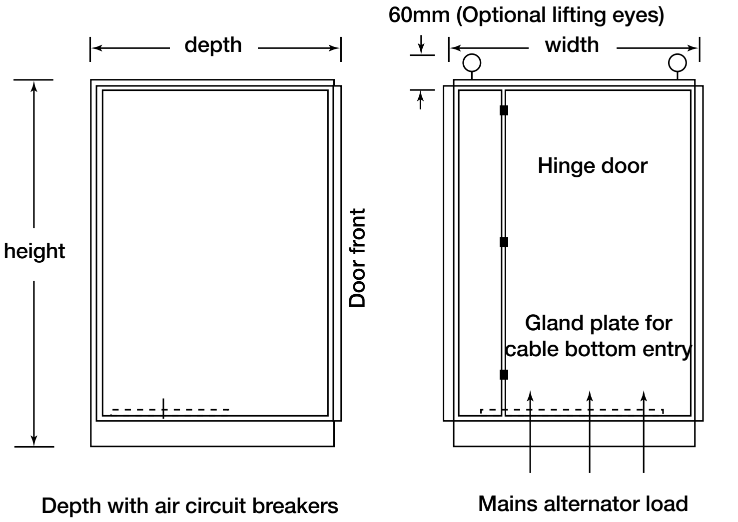


TABLE A

Contactor rating		Dimensions (mm)		
		Width	Height	Depth
40A	3 pole	400	500	210
40A	4 pole	400	500	210
60A	3 pole	400	500	210
60A	4 pole	400	500	210
80A	3 pole	400	500	210
80A	4 pole	400	500	210
125A	3 pole	400	500	210
125A	4 pole	400	500	210
200A	3 pole	600	800	300
200A	4 pole	600	800	300
270A	3 pole	600	800	300
270A	4 pole	600	800	300
350A	3 pole	600	800	300
350A	4 pole	600	800	300
500A	3 pole	800	1000	350
500A	4 pole	800	1000	350
700A	3 pole	800	1000	350
700A	4 pole	800	1000	350

Floor mounted cubicles for changeover air circuit breakers up to 6300 Amperes



For use where controls and instruments are mounted on set/panel

TABLE B

Floor standing changeover cubicles up to 6300 amperes

Contactor rating		Dimensions (mm)		
		Width	Height	Depth
1000A	3 pole	1000	1200	600
1000A	4 pole	1000	1200	600
1600A	3 or 4 pole	1000	2210	1350
2000A	3 or 4 pole	1000	2210	1350
2500A	3 or 4 pole	1000	2210	1300
3200A	3 or 4 pole	1000	2210	1300
4000A	3 or 4 pole	1344	2210	1520
5000A	3 or 4 pole	1344	2210	1520
6300A	3 or 4 pole	1500	2210	1520

Dimensions are for guidance only.
Specifications may change without notice.

The busbar system when fitted, is constructed from copper bars with bolted joints for all three phases, a full neutral, and a 1/4 x 2 inch ground bus extended through all sections. This system is a typical single busbar system as shown in Fig. D3.

Steady state bus ratings are based on a maximum of 1000amps/square inch current density, sized particularly for the breaker or the combined output of the total generators. In either case the busbars can be selected using the space requirements within the panel and the current capacity required.

Bus bracing levels range from 50kA to 200kA. The fault ratings on the busbars and all data can be found in the manufacturer's literature manual.

Generator Neutrals

The electrical output of generators is normally in four wire form, with the neutral point of the windings brought out. An out of balance current results where there is practical difficulty in balancing the single phase load across all three phases. This out of balance load flows through the neutral conductor. Current may also flow through the neutral during an earth fault. In common practice, the star point of the machine is connected to the neutral bar, which in turn is earthed. There is a possibility of large harmonic currents circulating in the interconnected neutrals when machines are paralleled. Careful consideration should, therefore, be given to the paralleling of neutrals in any system.

The neutrals of generators of dissimilar construction and differing output and power factor ratings, should therefore, never be interconnected. Switchgear such as neutral earthing contactors should be employed to cater for this, ensuring that only one machine star point is connected to the neutral bar at any one time. It is usual to connect the largest running machine in the system for this duty.

NOTE: where machines of similar types, are connected together and have the same operating loads and power factors, the neutrals can be connected in parallel.

Auxiliary Supplies Transformer

An auxiliary supply transformer may be required for the interconnection of high voltage equipment. This is mounted external from the complete package. This may be provided by Cummins or others as per the contract requirements.

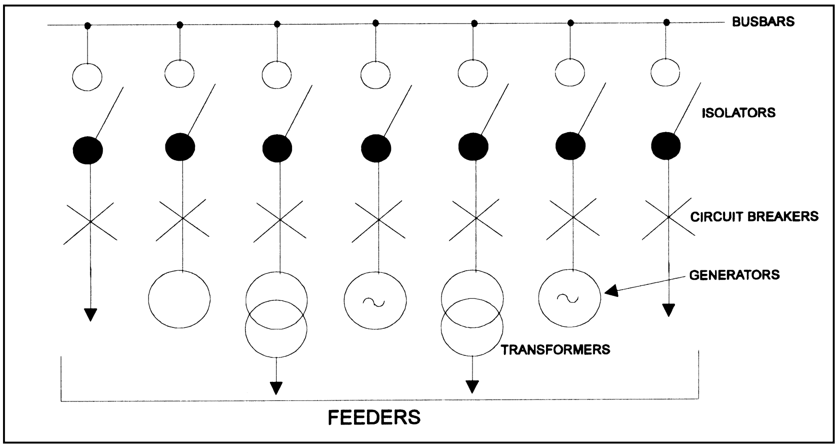


Fig. D3 Typical Single Busbar System

Typical System One-Line Diagram

Figure D4 is a one-line diagram of a typical electrical distribution system that incorporates an emergency generator set.

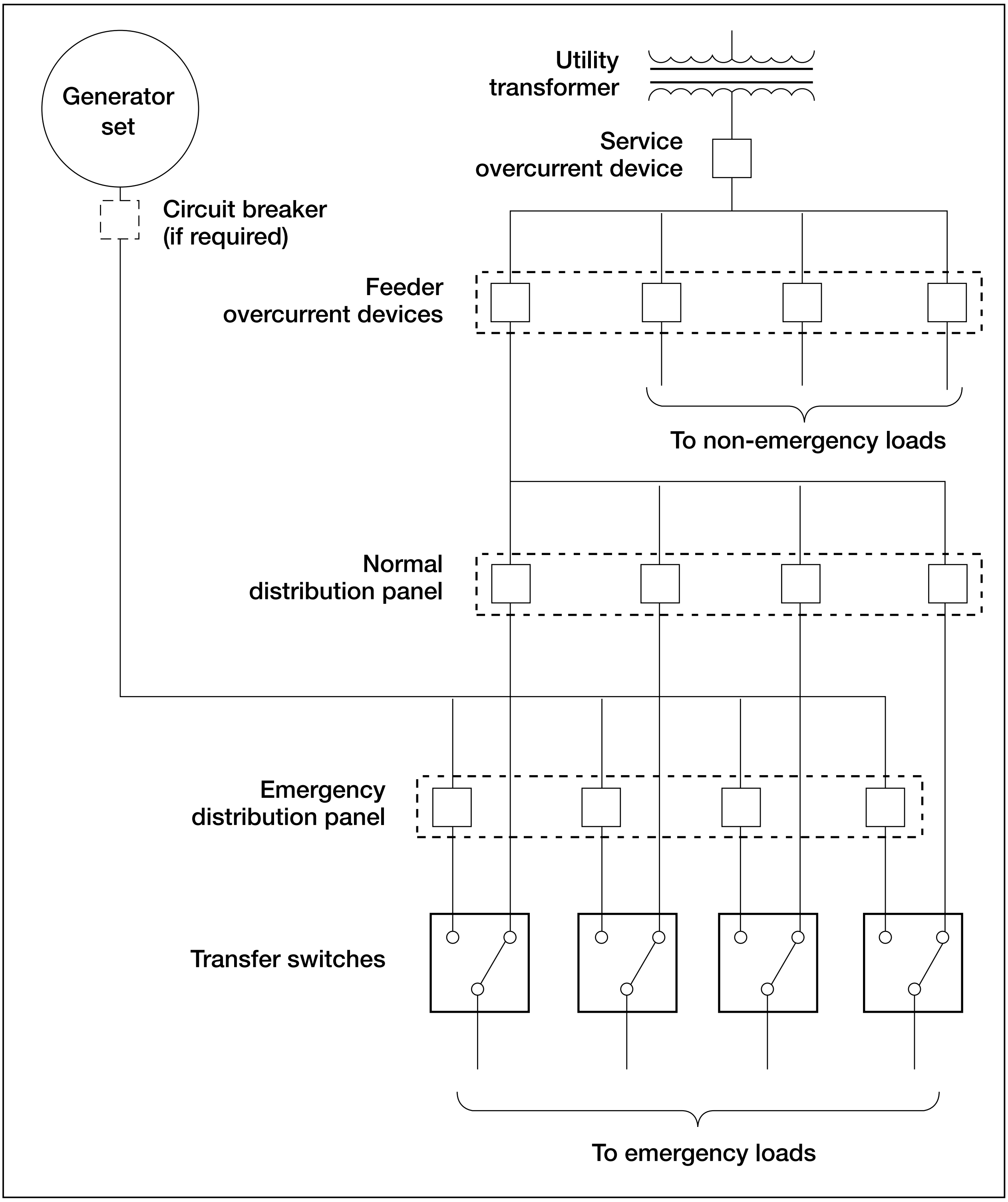


Figure D4 typical one-line diagram of an electrical distribution system

General

The cables in generator installations vary from multicored light current control and communication types to large single or multi core. They are installed in a variety of ways:

- In open runs directly attached to structural surfaces, such as walls beams and columns
- In trenches, open, enclosed or back-filled
- On cable trays
- In underground ducts
- In metallic or plastic conduits and trunking

The cable runs between genset and associated switchgear and control gear require to be as short as possible.

The factors that influences the selection of the conductor size are:

- Temperature
- Continuous, short-term, and cyclic loading requirements.
- The type of protection afforded against overload current.
- The fault level of the system, i.e. the power sources fault capacity
- Voltage drop considerations for the installation.

It is good practice to use a flexible cable to connect on to the alternator terminals in order to accomodate set movement. EPR/CSP or BUTYL cable is recommended for this purpose. If the switchgear panel is located at some distance from the genset it may be more cost effective to install a cable link box adjacent to the set to minimise the length of flexible cable needed. Main connections between the link box and switchgear panel and then to the distribution panel can then be in less expensive armoured cable.

All installations should have an isolator switch between the mains incoming supply and the plant control cubicle incoming terminals to enable maintenance to be carried out on the plant.

Flexible cable entry into control module and cable tray arrangement for side entry.

Cable Ratings

Cables must be chosen so that their current carrying capacity (related to the cross sectional area) is not less than the full load current they are required to carry. The continuous current rating of a cable is dependent upon the way heat is generated. Installation conditions have, therefore, to be taken into account when determining the size of the cable to be used. More often than not, the limiting factor in low voltage installations is the cable voltage drop.

The current carrying capacity of a cable is influenced by:-

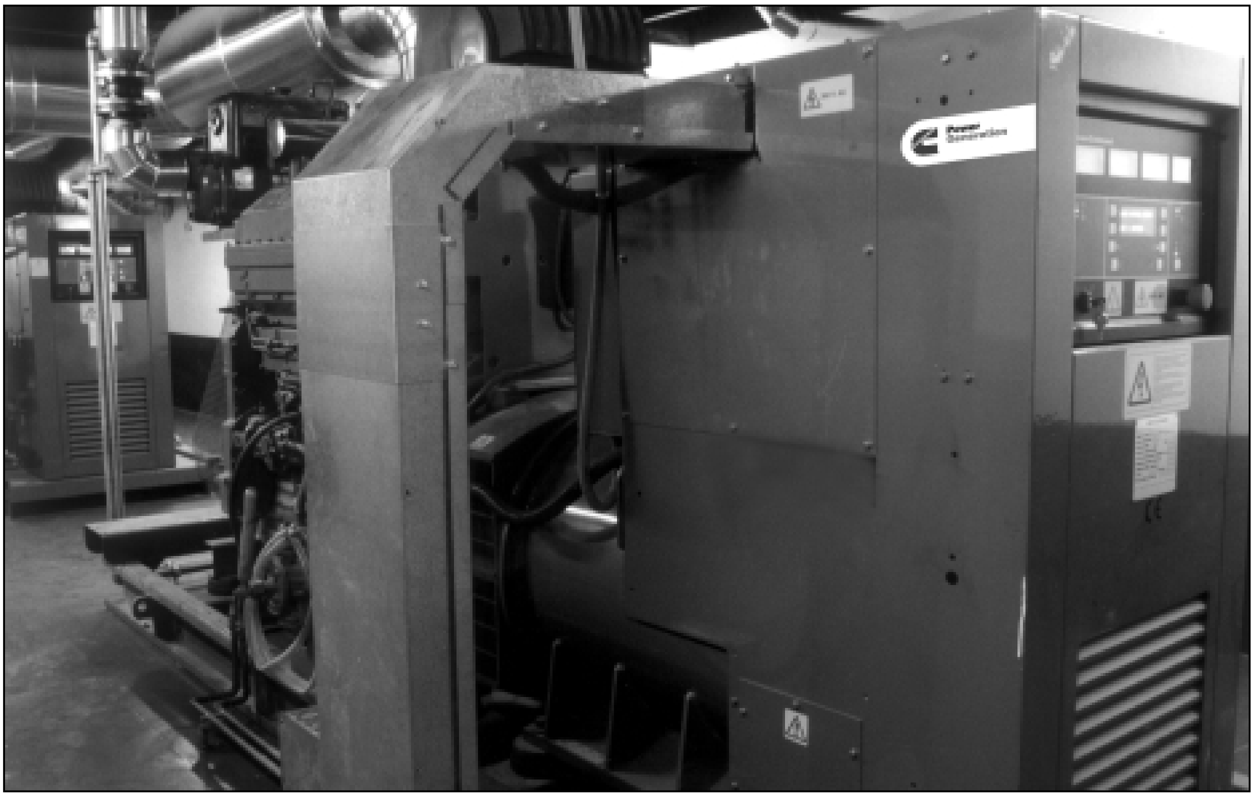
- Conductor material - copper or aluminium.
- Insulation material.
- The nature of its protective finishes - bedding, armouring or sheathing.
- The installation ambient temperature.
- The method of installation - be it, in open air, in trenches, buried, grouped with cables of other circuits.

In the UK, low voltage installations come within the scope of IEE Regulations. They must comply with the requirements of Regulation 522. This means using the methods for determining the cross sectional areas of cable conductors to comply with Regulation 522-1.

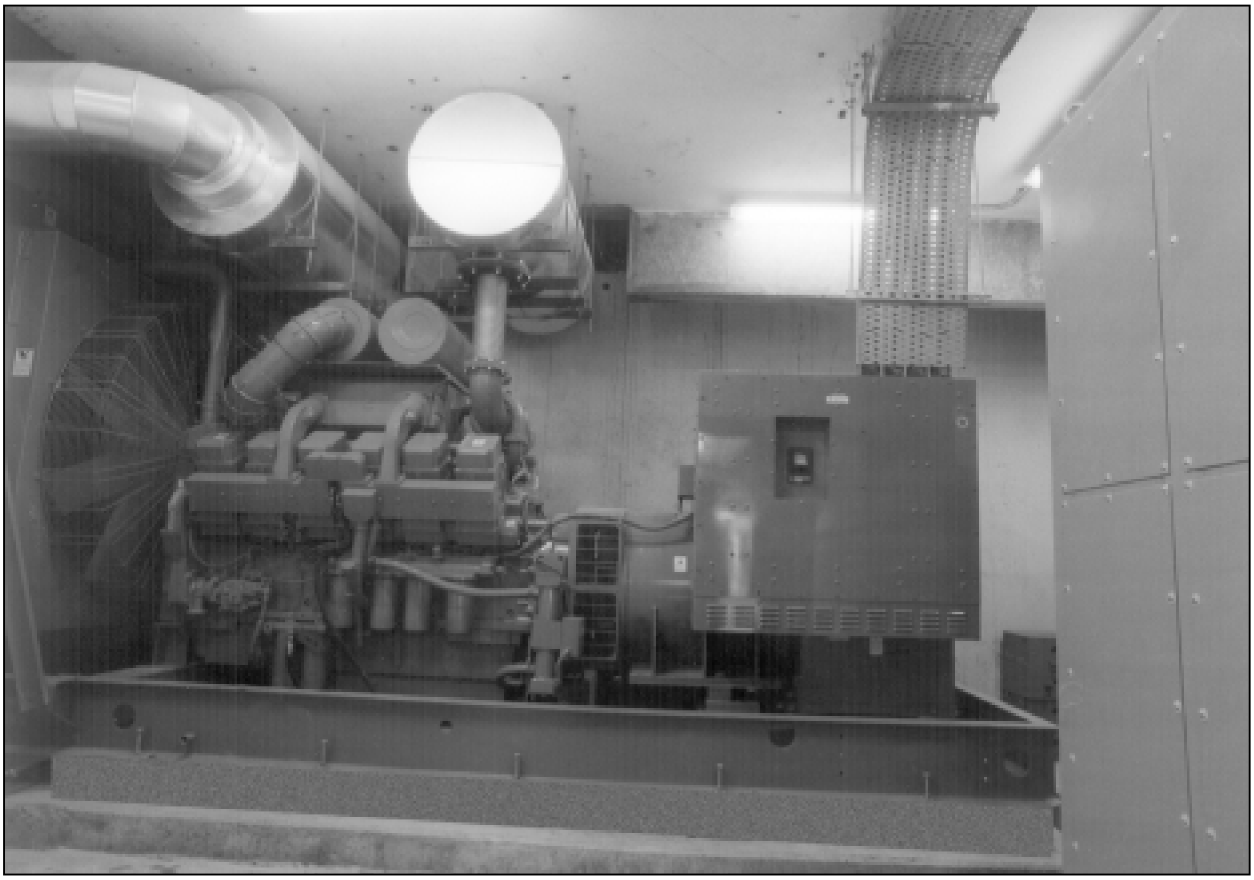
To obtain the on-site rating of the cable, the correction factors cover variations in ambient air and ground temperatures, depth of laying, soil thermal resistivity, and cable grouping. It is then possible to determine the actual rating for the cables installed in free air, in ducts, in trunking and conduit, and in open, enclosed and back-filled trenches.

Consult the manufacturers rating tables for details of cable rating and installation methods.

Top cable entry and overhead cable tray run between sets (1000 kVA sets).



Ducted side entry into access panel ensures a neat cable installation.



Top cable entry. Control panels provide choice of top or bottom entry. LH or RH mounted.
Neat cable top entry into control module using perforated steel cable tray and ceiling supports.

Methods of Installing Cables

Conduit Wiring Systems

- Screwed conduit of the welded type to BS 4568 or local code should be used.
- Surface conduits should be supported and fixed by means of distance saddles spaced and located within 300mm of bends or fittings.
- Runs must be earthed.
- The conduit system should be completely erected before cables are drawn in.
- A space factor of at least 40% should be provided.
- The inner radii of bends should never be less than 2.5 times the outer diameter of the conduit.
- Conduit systems should be designed so that they can be sealed against the entry of dust and water. Nevertheless, ventilation outlets should be provided at the highest and lowest points in each section of the system. These will permit the free circulation of air and provide drainage outlets for any condensation that may have accumulated in the runs.
- To maintain the fire resistance of walls, ceilings and floors, any opening made in them should be made good with materials to restore the fire integrity of the particular building element.

Trunking

- Steel trunking must comply with BS 4678
- Fittings must be used to ensure that bend radii are adequate.
- As with steel conduit, steel trunking may be used as a protective conductor provided it satisfies the IEE Wiring Regulations (in UK), it may not be used as a combined protective and neutral (pen) conductor.
- A space factor of at least 45% should be provided.
- Supports should be spaced at distances and ends should not overhang a fixing by more than 300mm.
- Trunking should not be installed with covers on the underside. Covers should be solidly fixed in passage through walls, floors and ceilings.
- On vertical runs internal heat barriers should be provided to prevent air at the topmost part of the run attaining excessively high temperatures.

Cable installation into PCC module with Digital Master Control (DMC) cubicle and wall mounted changeover contactor box adjacent to set.

Segregation of Circuits

Segregation of cables of different circuits will prevent electrical and physical contact. Three circuits are defined in the Regulations. They are:

1. LV circuits (other than for fire alarm or emergency lightning circuits) fed from the main supply system.
2. Extra low voltage or telecommunication circuits fed from a safety source (e.g. telephones, address and data transmissions systems).
3. Fire alarm or emergency lighting circuits.

Where it is intended to install type 1 cables in the same enclosure as telecommunication system which may be connected to lines provided by a public telecommunications system authority, the approval of that authority is necessary. Normally these can be installed in galvanically segregated trunking. Cables used to connect the battery chargers of self contained luminaries to mains supply circuits are not deemed to be emergency lighting circuits.

Cable Trays

The most common method for installing cables is by clipping them to perforated trays. The trays should be galvanised or protected with rust preventing finishes applied before erection. Cleats or clips should be of galvanised steel or brass.

Cables should be laid in a flat formation. The maximum spacing for clips and cleats should be 450mm.

Tray supports should be spaced adequately, usually about 1200mm.

Steel supports and trays should be of sufficient strength and size to accommodate the future addition of approximately 25% more cables than those originally planned.

Note: Plastic cable ties must not be used for securing power cables.

Digital Master Control Cubicle (DMC) installed with a water companies Switchboard Suite. Access to the DMC is all front entry.

Trenches

Trenches within plant rooms and generator halls should be of the enclosed type with concrete slab or steel chequer plate covers. (See Fig. D5).

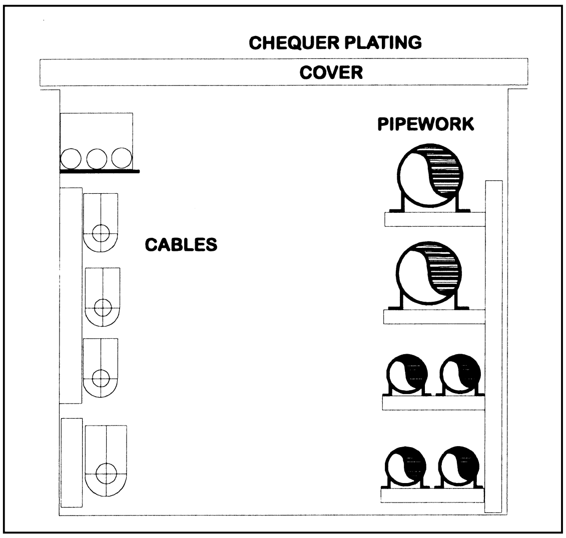


Fig. D5 Trench Construction

Trench bends should be contoured to accommodate the minimum bending radius for the largest cable installed.

Trenches should be kept as straight as possible. The bottoms should be smoothly contoured and arranged to fall away from the engine plinths so that water and oil spillages do not accumulate within the trenches but are drained away to a common catchment pit.

Trenches external to the building are often back-filled which should be consolidated before the cable is installed. This ensures that there is no further ground settlement. Back filling should be made in even layers.

Laid Direct in Ground

Depth of cables to comply with local codes.

Where armoured and sheathed cables are run external to the buildings and laid direct in the ground, they should be laid on a 75mm deep bedding medium.

Every cable in the layer should be protected by interlocking cable tiles (to BS2484).

The separation distances between HV and LV cables in trenches or laid direct in the ground should be between 160mm and 400mm, depending on the space available.

Cables passing under roads, pavements, or building structures should be drawn through ducts and must be of a type incorporating a sheath and/or armour which is resistant to any mechanical damage likely to be caused during drawing-in. The ducts should be laid on a firm, consolidated base. The ends of the ducts should always be sealed by plugs until the cables are installed.

No more than one cable should occupy a ductway, providing a number of spare ways for future cables (say 25% more than those initially required).

Cable Termination

The termination of any power cable should be designed to meet the following requirements:-

- Electrically connect the insulated cable conductor(s) to electrical equipment
- Physically protect and support the end of cable conductor, insulation, shielding system, and the sheath or armour of the cable
- Effectively control electrical stresses to give the dielectric strength required for the insulation level of the cable system.

It is only necessary on LV systems to apply tape from the lower portion of the terminal lug down onto the conductors extruded insulation. The tape should be compatible with the cable insulation. An alternative method is to use heat shrinkable sleeves and lug boots. Where cables are connected direct to busbars which are likely to be operating at higher temperatures than the cable conductors, high temperature insulation in sleeve or tape form is used.

Screened MV cables must be terminated at a sufficient distance back from the conductor(s) to give the creepage distance required between conductor and shield.

It is recommended that heat shrink termination kits is used on HV XLPE cables. These incorporate stress control, non-tracking and weatherproof tubes, cable gloves and termination boots.

Glands

Polymeric cables should be terminated using mechanical type compression glands to BS6121. The material of the gland must be compatible with the cable armour. Where the glands terminate in non-metallic gland plates they must be fitted with earth tags. Where glands are to be screwed into aluminium or zinc base alloy plates, use cadmium plated glands.

The gland must be capable of withstanding the fault current during the time required for the cable protective device to operate. Where a circuit breaker is used the fault clearance time could be near one second.

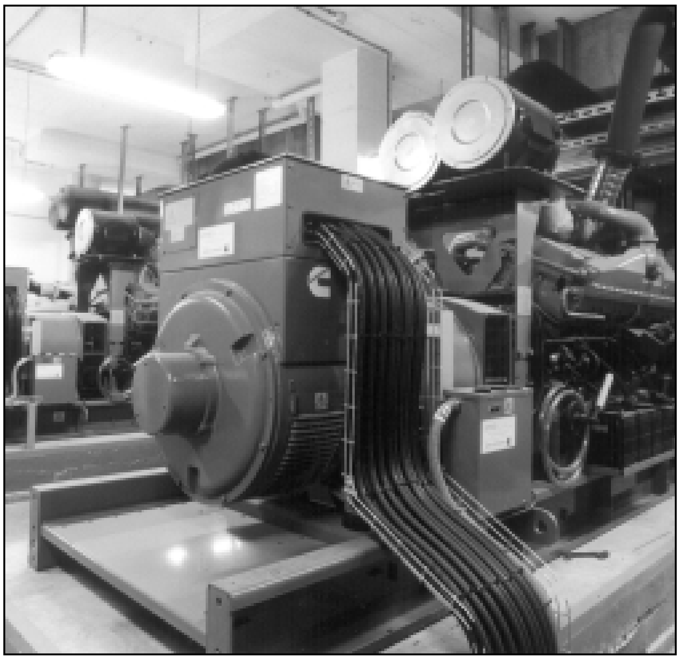
It is good practice to fit PVC or neoprene shrouds over armoured cable glands, particularly in outdoor applications.

Connections to Terminals

Power cable conductors are usually terminated in compression type cable lugs using a hydraulic tool. The hexagonal joint appears to be the most popular crimp shape for conductors over $25mm^2$. Insulated crimped lugs are used on the stranded conductors of small power and control cables. Soldered lugs and shell type washer terminations are now seldom specified.

Cable Tails

Cable tails from the gland to the terminals of the equipment should be sufficient length to prevent the development of tension within them. Allowance should be made for the movement of cables connected to the terminal boxes of any plant mounted on vibration isolators. In these circumstances, and where connections to the main switchboard are in single core armoured cable, or in multicore, unarmoured cable, it is usual to terminate in a free standing terminal box mounted as close as possible to the plant. Flexible connections, e.g. in single-core, PVC insulated or PVC/XLPE insulated and PVC sheathed cables, are then used between this floor mounting box and the plant terminals. The connections should be generously looped.



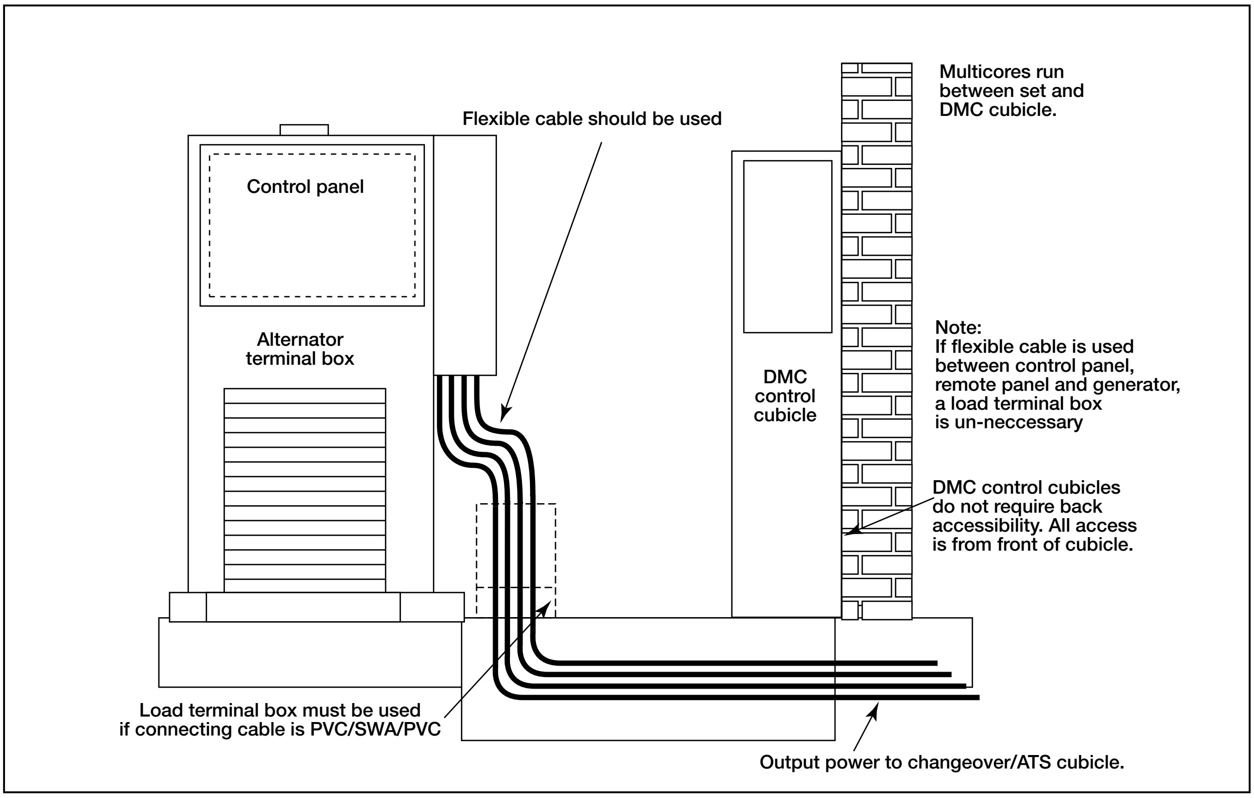


Fig. D6 Cable Connections – Cable Tails

General

During the design of a generator installation, consideration must be given to the earthing of the electrical system. The key reasons for earthing are:

- **To limit and stabilise the electrical potential of any part of the installation to a pre-determined level with respect to earth.**
- **To ensure that the voltage between any phase conductor of the system and earth does not exceed the phase-to-neutral voltage of the system.**
- **To ensure that the neutral point voltage does not rise significantly above earth potential.**
- **To provide a path for fault current to enable overcurrent protection to operate in the event of a fault.**
- **To ensure that extraneous conductive components nearby remain at or around earth potential.**

Earthing requirements can be broadly divided into two categories:

i) System earthing requirements – such as neutral earthing, provided to maintain the security of the electrical system.

ii) Equipment earthing – such as equipotential bonding, provided for ensuring the safety of humans and animals.

The application of system earthing depends largely upon the type of electrical system that is being designed. This will also be influenced by the characteristics of any other electrical system that may be connected to the generator, such as a utility supply. Equipment earthing is applied more universally and is less influenced by the electrical system characteristics.

Regulations and Codes

The generator and its associated equipment are provided with connection points for earth continuity conductors. The installer must ensure that the entire electrical system complies with local regulations as well as satisfying the needs of the installation. In the UK, installations should comply with BS 7671.

BS7430: 1998 – Code of Practice for Earthing – gives guidance on the earthing requirements for many common systems both in the UK and elsewhere. However it is essential that designers are familiar with local codes and regulatory requirements before proceeding with an installation.

If it is intended to use the generator to support any part of an installation normally supplied by a utility provider, the utility operator should be consulted before the generator is connected. This is particularly important if it is intended to parallel the generator with the utility supply.

Types of earth electrode

Although in many cases, the utility company may provide an earth terminal; **this alone should not be relied upon for private generation unless this use has been confirmed with the utility company.** A cable fault within the utility system may result in disconnection of the earth reference and therefore, for most generator installations, an independence earth electrode will be required. The size and type of this electrode will be determined by the resistivity of the soil in the location and by the requirements for sufficient fault current to operate the electrical system protection.

Types of earth electrodes may range from a single earth rod for a small generator in favourable conditions, to a large buried earth mat in dry or sandy soils. Conductive building reinforcement material and other fixed installations such as boreholes are also sometimes used to augment the earth electrodes. All electrodes should be buried or driven to a depth of at least one metre.

Because of the variability of soil types and resistivities, it is **impossible to make general recommendations as to the number or type of electrodes required.**

Due account should be taken of the seasonal variations in water table and soil moisture levels, both of which will greatly affect the resistance measurement of the earth electrode. Regular testing at various times of the year should be performed to ensure that an efficient earthing system is maintained.

The earth electrode must be fully established and tested before any attempt is made to start the generator. For neutral point solid earthing of generating plant, it is recommended that the measured earth electrode resistance should not exceed 20 Ohms at any time, regardless of the protection system used.

Solid and impedance earthing

Where reliance is placed on overcurrent for the detection of earth faults, as is normal on low voltage (below 1000 Volts AC) solid-earthed systems, it is **vital that earth impedances are kept as low as possible.** In many countries, including the UK, local codes and regulations prohibit the introduction of any impedance in a low voltage neutral-earth path. The value of the earth loop impedance that is determined for the installation will be the sum of all the impedances in the earth path, such as those of the generator windings, the installation cables and earth conductors and the earth electrode resistance itself.

For high voltage generators, where less reliance is placed on the need to produce an overcurrent situation in the event of an earth fault, **impedance earthing is usual and will often take the form of a resistance in the neutral-earth path.** The value of this resistance will be determined by the need to discriminate through the system, to avoid tripping the source in the event of a downstream fault.

Unearthed neutral systems are sometimes encountered, both at high and low voltages. In this case, however, **special consideration must be given to the need to suppress high transient voltages that may arise from arcing faults to ground in the predominantly inductive circuit environment.** These voltages may exceed the rating of the insulation of the system, particularly where wound components, such as generators or transformers are present.

Low voltage generators (below 1000V) (Figs 1, 2 & 3)

For most industrial, commercial and mobile applications, **these generators will have solidly earthed neutrals, without significant impedance in the neutral-earth path.** Exceptions to this rule exist in marine and specialised land-based applications; where it is desirable for the generator to continue in operation with a single earth fault present.

Other reasons may preclude the possibility of passage of large earth-fault currents, such as the presence of flammable liquids or gases. These may dictate that the system should not be referenced, however, in these cases, earth-fault detection equipment is normally provided to warn of the presence of the fault. A high impedance earth (rather than an open circuit – to suppress over voltage) is usually combined with a voltage sensitive relay to detect the presence of an earth fault.

Most Cummins Power Generation LV products fall into one of three categories:

i) Generators which are intended operate independently of an external supply (e.g. 'prime-power' operation);

ii) Generators that provide a changeover or alternative supply; and

iii) Generators that can operate in parallel with an external supply.

Cases ii) and iii) are often combined for a no-break changeover installation. While the equipment earthing requirement is similar for all schemes, the system earthing requirements are different for each of these situations and unless this is fully resolved at the design stage, the utility provider may refuse to connect the installation to the mains supply.

Note:

a) All Cummins Power Generation sets are provided with earth bonding in accordance with British standards. Earthing points are notated with clear identifying labels and include links between the power pack to the sub chassis, between antivibration mounts and the main chassis and links between the control panel and the main earthing point. Cables are in the regulation yellow and green colours, of adequate capacity and provision for connecting the main earthing points from the generator to ground via a substantial brass threaded bolt and locking nuts and washers.

i) Generators that operate independently of an external supply and in parallel

These generators provide the only source of electrical power to the system to which they are connected. Earthing is normally achieved by establishing a suitable electrode installation as above and then connecting the generator neutral and all extraneous metalwork to the electrode installation terminal.

For multiple generator installations, where the generators are capable of operating in parallel, the design of the electrode system must take into account the possibility of any number of the installed generators being connected at any one time. In addition, the possibility of circulating currents in the neutral-earth path may arise and this is dealt with later in the article.

No matter how temporary a generator system, the need for efficient earthing is the same as with a permanent installation.

ii) Generators that provide a changeover or alternative to an external supply

In this case, the generator is able to supply part or all of the installation in the event of a failure of the external supply. The generator is never allowed to parallel with the utility supply.

When designing an installation of this type, ensuring the correct segregation of the system when fed from the generator installation, as opposed to the externally supplied case is essential. The need to segregate will depend largely on the design of the external system and it is therefore vital to enlist the assistance of the utility provider to ensure that the correct decisions are made and to avoid costly delays.

As a general rule, **phase and neutral isolation should be applied,** resulting in a need for 4-pole changeover switchgear. The exception is where a multiple-earthed system (such as PME – protective multiple earth) is known to be provided by the utility supplier. In this case, the neutral conductor is also used as a **protective conductor** within the distribution system and bonding and continuity throughout the entire system is essential.

Typical Earthing Arrangements

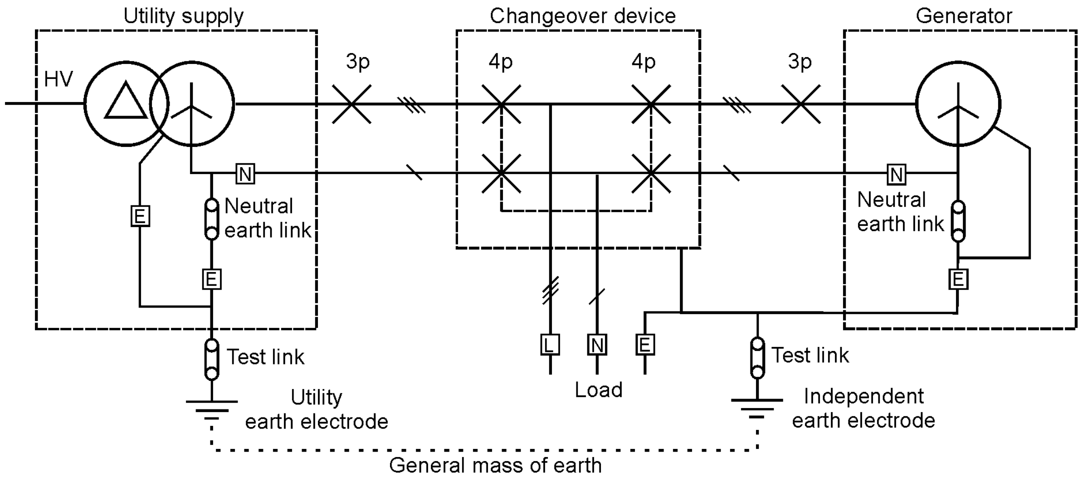


Figure 1: Generator installation for a low-voltage, conventional earthed-neutral utility supply, with 4-pole interlocked changeover switchgear and independently earthed generator installation.

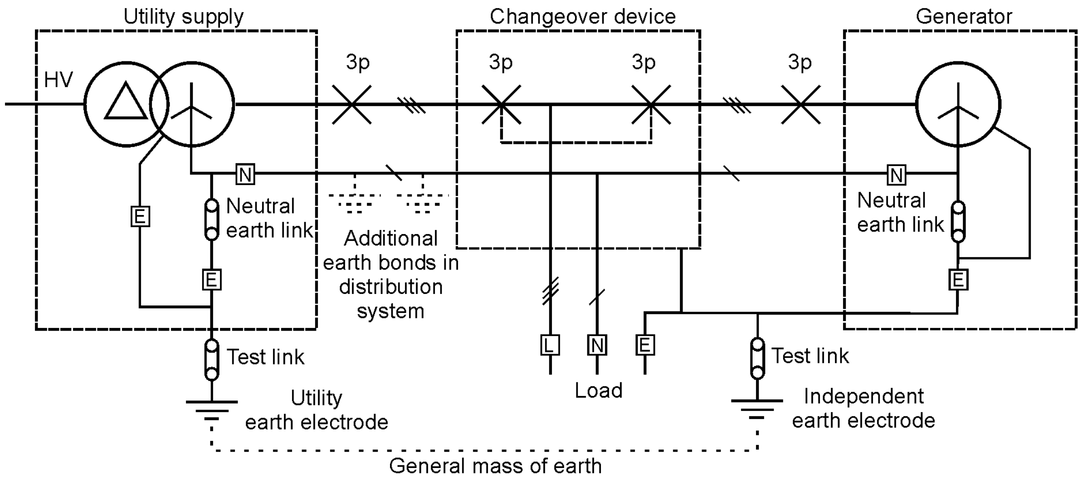


Figure 2: Generator installation for a low-voltage, combined protective and neutral conductor utility supply (PME), with 3-pole interlocked changeover switchgear and independently earthed generator installation.

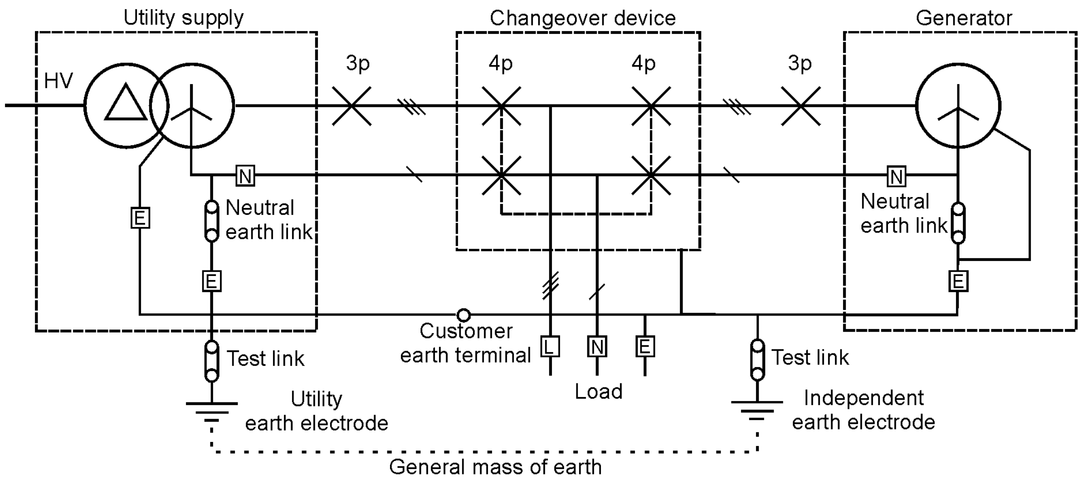


Figure 3: Generator installation for a low-voltage, conventional earthed-neutral utility supply, with earth terminal provided by utility company, 4-pole interlocked changeover switchgear and independently earthed generator installation.

Generators that operate independently of an external supply and in parallel.

Multiple low voltage generator installations.

Even in these cases, independent earth electrodes should be provided for the generator-supplied system, as it is possible that a cable fault could result in disconnection of the earth reference. These electrodes will also form a part of the utility supplier's system and earthing conductors connected to them must be sized in accordance with local regulations.

Changeover switchgear must be arranged so that accidental parallel operation with the external provider's system is not possible. This may be satisfied by the design of the changeover switch alone; however where discreet contactors or circuit breakers provide the method of changeover, electrical and mechanical interlocks will be required.

Once the isolation of the systems has been resolved, the design of the earthing system will follow similar lines to the independent operation case above, with the neutral (star) point of the generator and all extraneous metalwork connected to the earth terminal for solidly earthed systems. For multiple generator installations care must again be taken to resolve the possibility of circulating currents in the neutral-earth path.

iii) Generators that can operate in parallel with an external supply.

Parallel operation of generators with an external supply is becoming increasingly frequent and falls into one of two categories:

i) Short time occasional parallel operation (less than 5 minutes in any month) for the purpose of transfer of supply without disturbance; and

ii) Longer term or more frequent parallel operation.

The key distinguishing feature between the two systems lies with the need to protect against the possibility of loss of the external supply when the generator is operating in parallel and does not significantly affect the design of the earthing system.

In most cases, apart from the multiple earth case referred to above, **the external provider will insist on the neutral-earth reference being removed from the generator when operating in parallel with the utility.** This eliminates the risk of circulating currents through the earth path and avoids the possibility of the system earth fault protection being compromised by the presence of an additional reference.

For the multiple earthed system case, the decision whether to reference the generator star point or not will depend more upon the likelihood of circulating currents. Where there is doubt, **assume the need to isolate the generator neutral-earth reference when in parallel with an external supply.**

Where neutral earth switchgear is used, take care to ensure that the earth reference will remain in place under all fault conditions. The control and protection scheme should also include for the detection of an incorrect neutral-earth configuration in the event of a control failure.

Regardless of the number of generators or the method of neutral point earthing, the extraneous metalwork of the generator and installation should remain effectively earthed at all times.

Multiple low voltage generator installations (Figs 4 & 5)

Where more than one generator is simultaneously connected to the same electrical system, a possibility exists for circulating currents (usually third harmonic) to flow through the windings of the generators. This will particularly affect the neutral and therefore neutral-earth connections, where third harmonic currents are additive.

There are several methods of overcoming circulating current problems:

i) Use of generators that have low third harmonic outputs. These usually employ two-thirds pitched windings or may be zigzag connected;

ii) Use of star point switching, similar to the parallel operation with the utility case above; or

iii) Use of a reactor in the neutral path that has negligible impedance at power frequency but that can attenuate higher frequency currents.

Most Cummins Power Generation LV generators employ two-thirds pitched windings as a means of controlling third harmonic circulating currents. **However, always verify this with the factory before proceeding** with any design as individual project variations may mean that this configuration is not possible.

If method ii) is used, take care to ensure that protection is included for the possibilities of either:

a) Two or more neutral earth switches being closed at the same time; or

b) An earth switch failing to close and provide a system reference.

Method iii) can be a cost-effective solution but requires care in application to avoid the possibility of elevating the star point voltage under fault conditions; or where significant levels of third harmonic currents exist.

Typical Earthing Arrangements

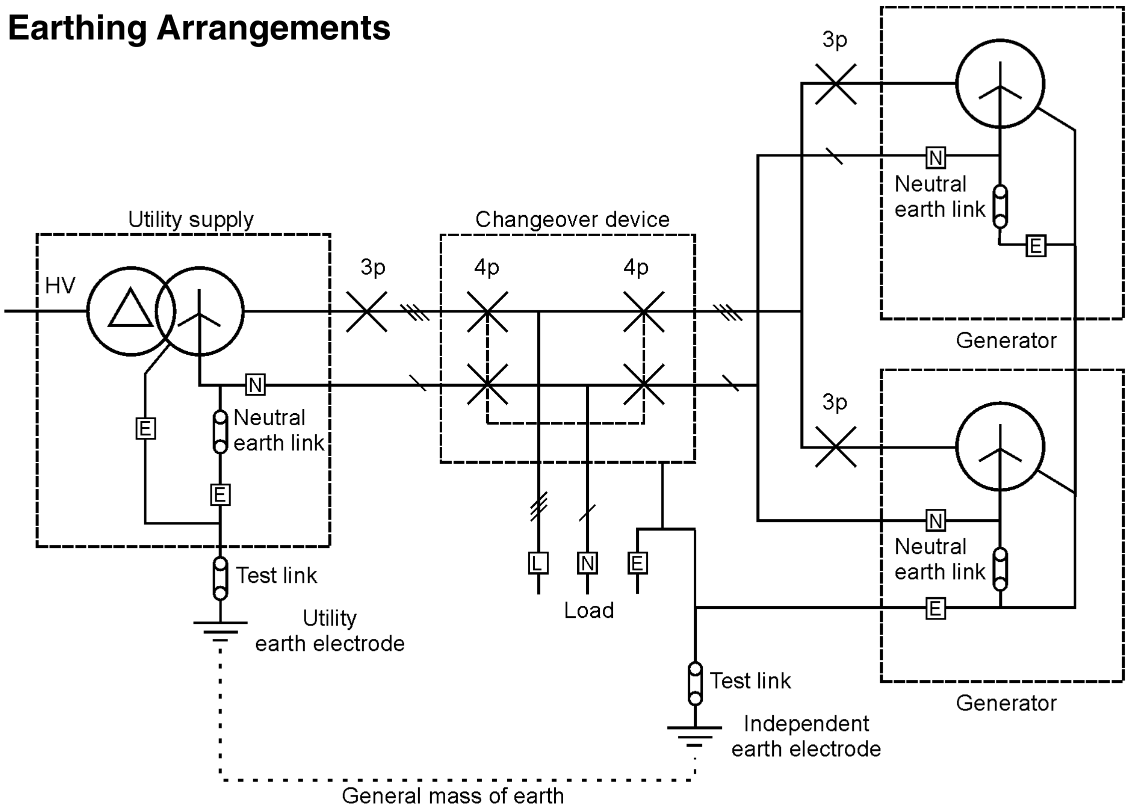


Figure 4: Multiple generator installation for a low-voltage, conventional earthed-neutral utility supply, with 4-pole interlocked changeover switchgear and independently earthed generator installation. The generators are designed for low third harmonic production

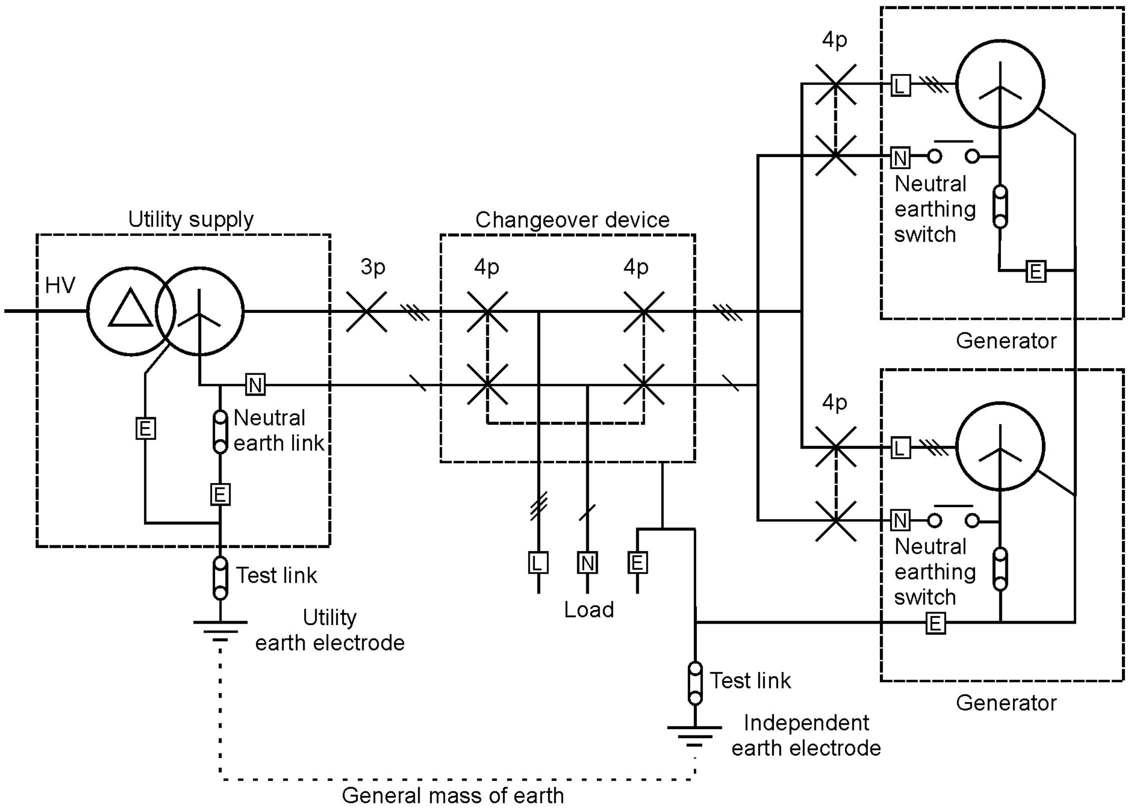


Figure 5: Multiple generator installation for a low-voltage, conventional earthed-neutral utility supply, with 4-pole interlocked changeover switchgear and independently earthed generator installation. The generators are provided with neutral earthing switchgear to minimise the effects of third harmonic circulating currents

Earth fault protection for low-voltage generators

Earth fault protection is becoming more frequently used in many European countries, especially in generator installations. It is important to check the local rules and regulations for the use of earth fault protection and maximum allowed earth fault currents.

For permanent installations with low values of earth-fault loop impedance, the EEBADS (Earthed Equipotential Bonding and Automatic Disconnection of Supply) principle may be used to provide protection against earth faults. In this case, the presence of an earth fault causes a high current to flow in the faulted phase and earth conductors, which is detected by the overcurrent protection fitted to the generator. See BS 7671 for more details.

The initial fault current may be as much as 15 times full load current for a single-phase low-impedance fault with full asymmetry. The distribution system, switchgear and cables associated with the entire system must be able to accommodate these values and decrement curves showing the performance of the generator under fault conditions are available.

The Cummins Power Generation 'Amp Sentry' protection, fitted to Power Command Controlled generator sets will control the generator output to produce up to three times full load current, after the initial high value has decayed, for approximately 8 seconds to allow the downstream protection to operate.

Where higher values of earth-fault loop impedance exist that may prevent application of the EEBADS principle, for personnel protection, or where it is necessary to detect damaging internal faults on larger machines, earth fault protection may be applied. This will take one of two forms:

- i) Unrestricted earth fault protection; or
- ii) Restricted earth fault protection.

Unrestricted earth fault protection

A single current transformer is installed around the generator star point-to-earth connection. A current-sensitive relay connected to this current transformer will detect the presence of an earth fault anywhere within the electrical system supplied by the generator.

This type of protection works well as a back-up to protection elsewhere in the electrical system, but if used as a primary protection, may cause nuisance tripping if set to values suitable for final sub-circuits.

Particular care must be taken if applying unrestricted earth fault protection to generators operating in parallel. If the generators are operating with their neutrals coupled, the relatively small values of circulating currents that always exist in this configuration may cause the earth fault protection to operate. If the generators are configured to operate with only one star point earthed, then the generator that is providing the system reference, and therefore the earth fault current, will be tripped.

If unrestricted earth fault protection is required for paralleling generators with coupled neutrals, the star points should be joined together, via removable links, and then taken to earth via a single conductor, around which the current transformer is fitted. The earth fault relay is then used to trip all generators simultaneously.

Restricted earth fault protection

Application of restricted earth fault protection enables zones of protection to be created allowing more sensitive protection without the risk of nuisance tripping. A common form of restricted earth fault protection is alternator winding protection where relatively low values of earth fault current can be detected and tripping initiated almost instantaneously, limiting winding damage on larger machines.

Restricted earth fault protection is normally applied by summating the phase and neutral currents and detecting the residual current left after the summation, which even for an unbalanced load should equal zero.

This requires the use of either a single core-balance CT, encompassing all phase and neutral conductors (though NOT the neutral-earth conductor), or two or four current transformers for single or three-phase systems respectively. The neutral-earth link for the electrical system is positioned outside of the **protection zone** and thus, for generator earth-fault protection, must be sited on the load side of the restricted earth protection current transformer(s).

When using two or four current transformers, care must be taken in the selection of these to ensure that their magnetisation curves are identical, as otherwise the **protection may not be stable under through-fault** (i.e. faults outside of the protection zone) conditions.

When fitting the current transformers, their orientation in the circuit (P1/P2 and S1/S2) is critical and most cases of nuisance tripping of restricted earth fault protection can be traced to incorrect current transformer orientation or wiring errors. The secondary wiring connecting the current transformers and relays together must be sized to avoid excessive burden on the current transformers.

Personnel protection

Where damage to the electrical system is envisaged, or in conditions where electric shock is more likely, such as Construction Site Installations, with silenced generators a Residual Current Device or RCD can be fitted to supplement the protection already provided. The RCD may be supplied with the generator, as a factory fitted option, or may be fitted within the on-site distribution system.

The RCD operates as a form of restricted earth-fault protection and in this case, the protection zone is the connected load. To provide personnel protection from electric shock on small portable or transportable generators, used as a final source of supply for hand-held equipment, an RCD with a setting of 30mA with a trip time of 40mS at a fault current of 150mA should be selected.

Care should be taken when applying this method of protection to larger generators that are intended to act as a source to a distribution system, as **discrimination will be difficult to achieve.** In this case, a relatively minor fault anywhere on the electrical system may result in sudden loss of supply to the entire system, producing undesirable and possibly hazardous effects. The RCD for personnel protection should be applied at the point of final distribution in these cases.

For RCD personnel protection to operate reliably, it is essential that the neutral conductor is connected to earth and extraneous conductive parts should be bonded together and to earth. This will help to avoid the existence of possibly hazardous touch voltages in the event of a fault.

RCD devices, along with all other protection equipment should be tested regularly by a competent person.

High voltage generators (above 1000 V)

Similar principles apply as with low voltage generators. However, the earthing of high voltage generators (i.e. those operating at a voltage of greater than 1000V AC measured phase-to-phase or phase-neutral), requires special consideration as in these cases, the risk of potentially lethal touch voltages existing under fault conditions is much greater.

The design of high voltage generator installations requires care in order to ensure that the various high and low voltage electrical systems are compatible. In particular, if high voltage generators are to be used in conjunction with an external supply, the utility company should be consulted at an early stage in the design process. **Most utility companies operate strict rules in relation to the connection of private high voltage generation to their distribution systems.**

In many countries, specific safety rules apply to high voltage systems and the system design and support infrastructure, including building; access and skilled staffing arrangements must consider this.

Impedance earthing

In order to reduce the stress on system components under earth fault conditions, resistance or reactance earthing is often employed, particularly on high voltage distribution systems and generators sized at over 1 MVA. The impedance will also assist in limiting the touch potential caused by the passage of large fault currents within the earth path.

The sizing of earthing resistors or reactors is mainly governed by the need to be able to discriminate fault protection throughout the electrical system. A starting point is to size the earthing resistor or reactor to allow the passage of the full load current of one generator with a phase solidly grounded, but this can vary according to the system design. Where a generator is to be used in conjunction with an external supply, the earthing installation must be designed in conjunction with the utility operator.

A high neutral-earth impedance value may limit earth fault currents to values insufficient to operate the protection within the electrical system without the risk of nuisance tripping. Too low an impedance value may allow excessive fault currents to flow, resulting in equipment damage, and increasing the risk of hazardous touch voltages.

The resistor or reactor should be rated to operate for the predicted duration of the fault clearance process, usually 10 or 30 seconds and should be provided with back-up protection to ensure that the unit does not overheat in the event of protection system failure.

The value of the earth electrode impedance should be taken into account when calculating the value of the neutral earthing impedance.

Generator transformers

As an alternative to direct high voltage generation, a low voltage generator may be provided with a transformer.

The generator transformer is normally a conventional double-wound unit, which will provide isolation between the high voltage and low voltage systems. In this case, the generator, low voltage connection to the transformer and the transformer LV winding are treated as a separate low-voltage electrical system and earthed accordingly.

If auto-transformers are considered for this application great care will be needed to ensure that the insulation of the low voltage system is not over-stressed under fault conditions and the LV generator will normally be considered as HV for safety rules purposes. For this article, only the double-wound case will be considered.

The winding configuration of the transformer will depend upon the generator application and the electrical system design. In general, a delta winding should be included wherever possible as this will help to attenuate third harmonic voltages.

The conductive casing of the transformer is treated as an extraneous conductive part and is earthed.

High voltage generation schemes (Figs 6-10)

Because of the varied methods of generation at high voltage, there are a greater number of potential schemes to be considered. These are:

Single HV generators and low voltage generators with transformers:

a) Operation in isolation from external supplies;

b) Operation as an alternative to an external supply; and

c) Operation in parallel with an external supply.

Multiple HV generators and low voltage generators with transformers:

d) Operation in isolation from any external supply;

e) Operation as an alternative to an external supply; and

f) Operation in parallel with an external supply.

g) Mixed generation schemes where low voltage generators with transformers and high voltage generators operate in parallel are a special case and are considered separately.

In addition, generators that are installed only to operate in parallel with an external supply, such as in combined heat and power systems are considered.

a) Single generators operating in isolation from external supplies.

This is similar to the low voltage case, where the star point of the generator is normally connected to earth, via a test link and earth electrode. **All extraneous metalwork is connected to the earth terminal to avoid the possibility of high touch potentials existing under fault conditions.**

For most high voltage generator systems, it is normal for the star-point earth connection to include a resistance or reactance for the reasons discussed above. The impedance will be provided with a high voltage connection terminal, which must be connected to the generator using a suitable rated cable for up to the phase-to-neutral voltage. **The low voltage side of the earthing impedance will be connected to the earth terminal, via a bolted test link, using conventional earthing conductors.**

For low voltage generators provided with a transformer, a delta connected transformer LV winding is normally used, the delta winding providing a path to attenuate third harmonic currents. The star point of the generator is solidly earthed. A star connected HV winding is usually provided and is earthed as for the high voltage generator case. If a delta connected HV winding is used, the electrical system may be referenced via separate earthing transformer.

b) Single generators operating as an alternative to an external supply

For high voltage generators and low voltage generators equipped with transformers, the application is similar to the isolated case a) above, since HV system neutrals are not usually distributed, as would be the case for LV systems. **Care must be taken to interlock the switchgear to avoid the risk of accidental parallel operation of the two systems,** since this would effectively apply an additional reference to the external system. For manual changeover schemes a system of key interlocks may be used, while automatic schemes will require the use of electrical interlocking.

c) Single generators operating in parallel with an external supply.

These systems require considerable care in design and **neutral-earth switching will be required in most cases;** in order to avoid placing an additional earth reference on the external system, which may compromise the protection scheme of this system. The neutral-earth switching is provided either for the generator star point earth, for HV generators; for the generator transformer star-point earth, for LV generators operating with transformers; or for the neutral earthing transformer star-point earth connection.

The neutral-earth switchgear must be rated to pass the current that will flow under all fault conditions and must remain closed while fault clearance is in progress. The control system logic must allow the switch to be closed at all times except when the generator is operating in parallel with the external supply system. **In the event of loss of the external supply while running in parallel, the neutral-earth switch must be immediately closed in order to maintain generator system reference.**

Apart from the introduction of the neutral-earth switch, which will be sited on the HV side of any impedance, generator system earthing will be as for the isolated case above.

d) Multiple generators operating in isolation from any external supply.

When designing a scheme involving multiple HV generators, it is important to ascertain whether the generators can be operated in parallel with each other with their **star points coupled, as this can result in significant savings in switchgear costs.**

If the generators can be operated with their star points coupled, then star point earthing may be applied similar to case a) above, with the multiple generators being treated as one. Impedance earthing of the star points is normal in this case.

Typical Earthing Arrangements

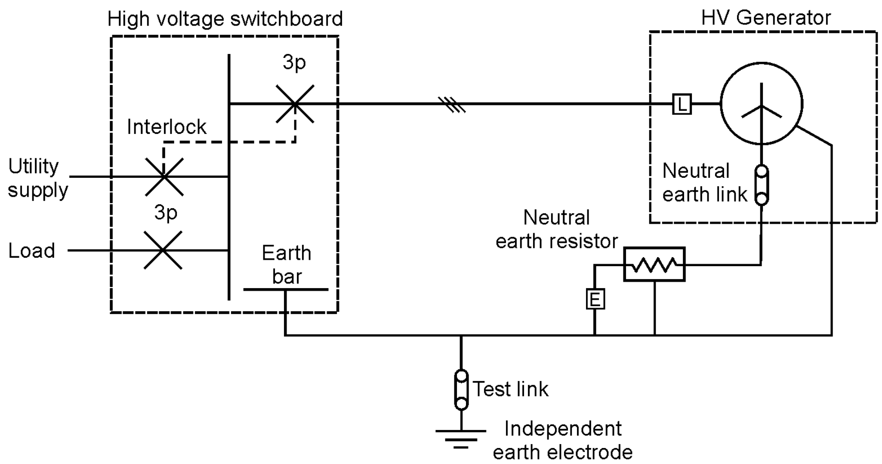


Figure 6: Single standby generator installation for a high-voltage, earthed-neutral utility supply, with interlocked changeover switchgear and independently resistance-earthed generator neutral.

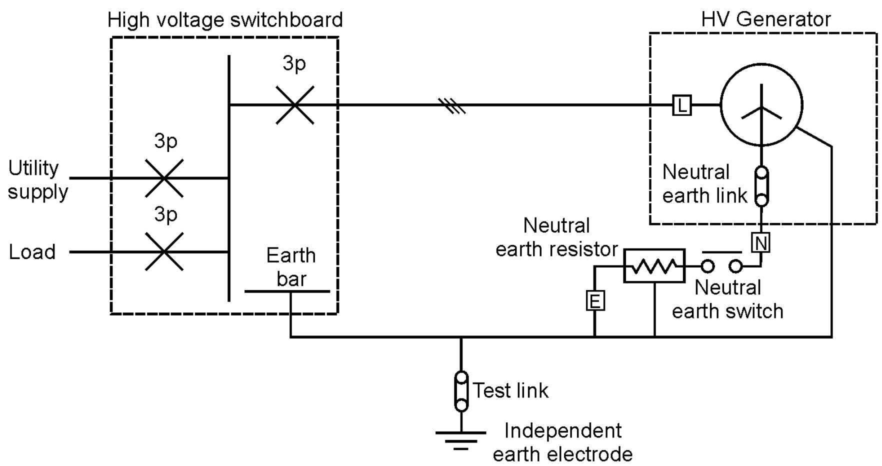


Figure 7: Single generator installation for a high-voltage, earthed-neutral utility supply, suitable for standby or parallel operation with a utility supply, with independently resistance-earthed generator neutral.

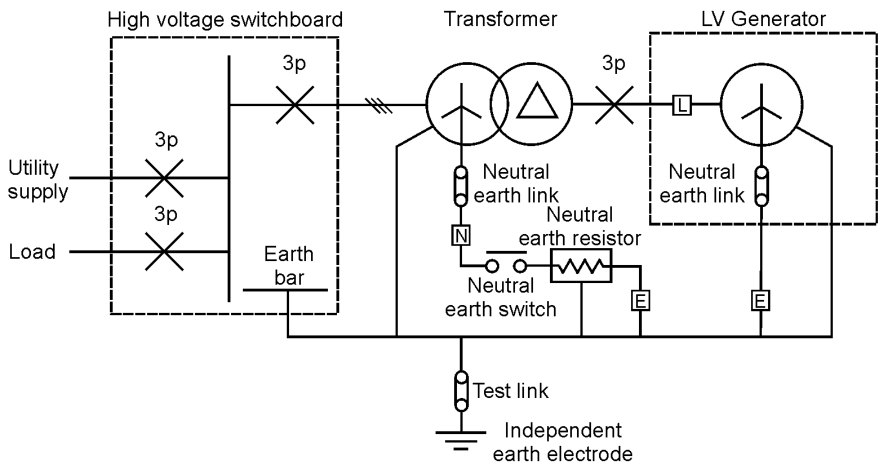


Figure 8: Single LV generator installation for a high-voltage, earthed-neutral utility supply, suitable for standby duty or parallel operation with a utility supply, with independently resistance-earthed generator-transformer neutral.

Typical Earthing Arrangements

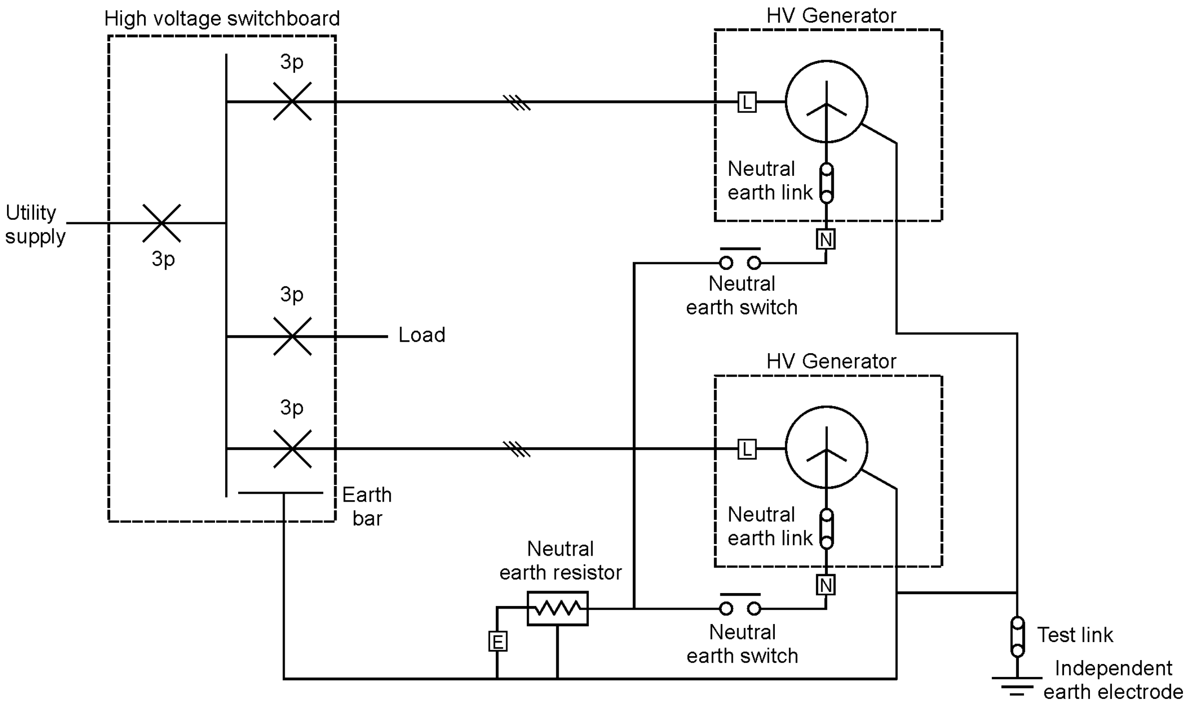


Figure 9: Multiple high-voltage generator installation for a high-voltage, earthed-neutral utility supply, suitable for standby or parallel operation with a utility supply, with independently switched and resistance-earthed generator neutrals..

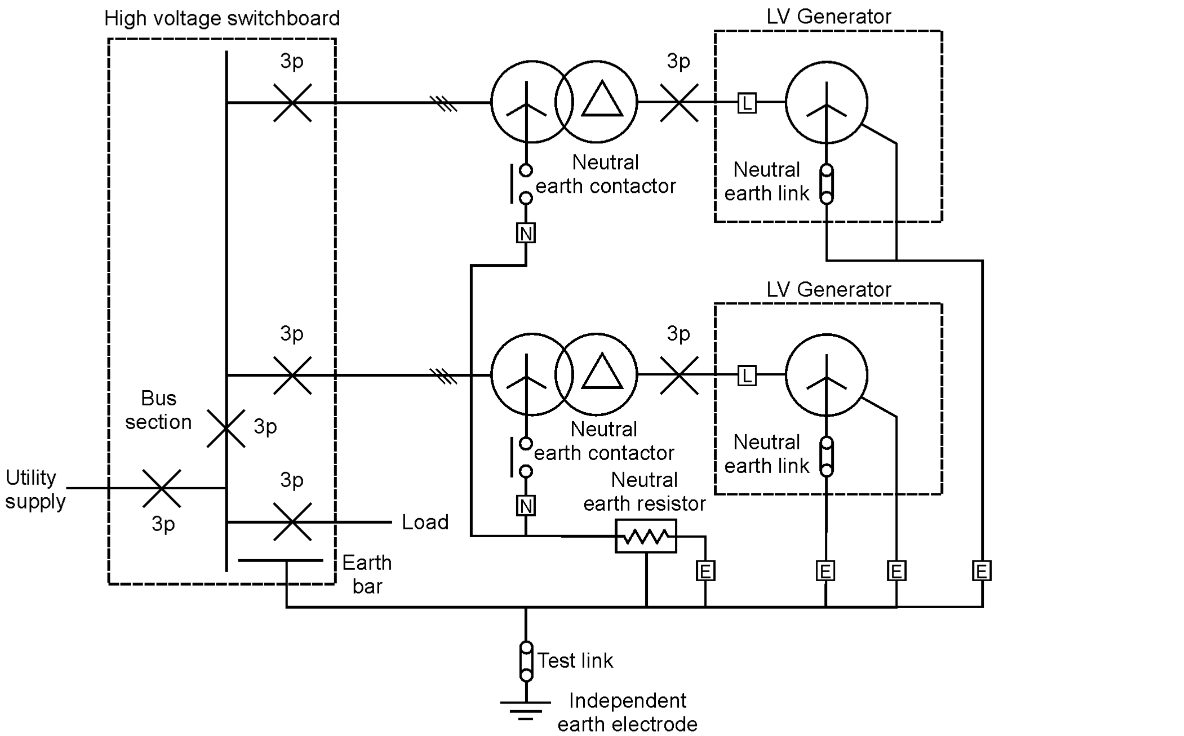
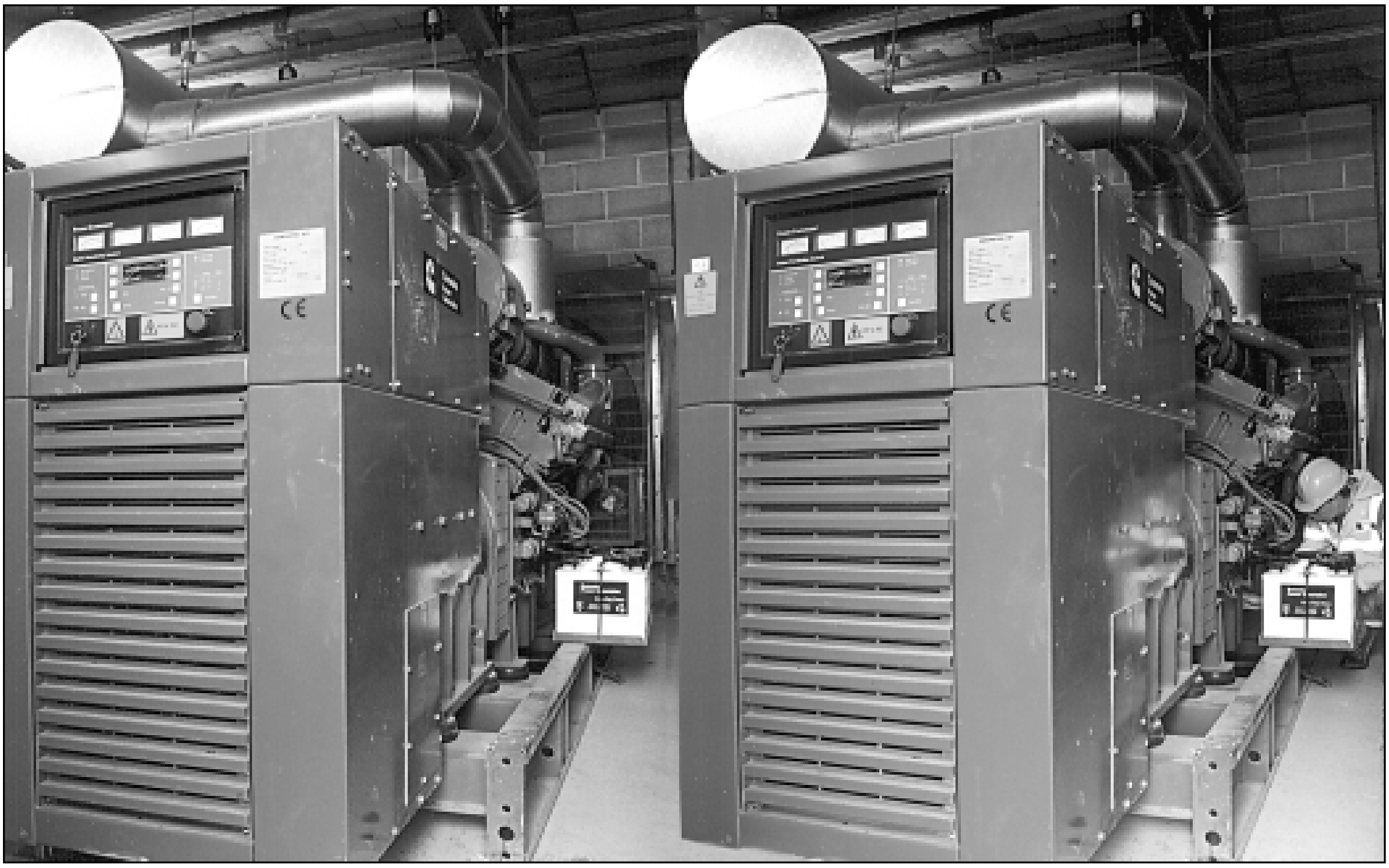


Figure 10: Multiple LV generator installation for a high-voltage, earthed-neutral electrical system, suitable for standby duty or parallel operation with a utility supply, with independently switched and resistance-earthed generator-transformer neutrals. The diagram illustrates the use of a bus-section to control load application.

High voltage multiple generators operating in isolation from any external supply.



Particular care must be taken if applying unrestricted earth fault protection to generators operating in parallel.

Consideration must be given to isolation of the generators for maintenance, since the HV side of the neutral earth impedance, to which all generator star points will be connected, is capable of rising to phase voltage, with respect to earth, under fault conditions. In this case, access to any generator's terminals and high voltage conductors can only be granted if all generators connected to the impedance are shut down, locked off and their high voltage conductors earthed. **This may be an important consideration for prime power schemes.**

Where generators cannot be operated in parallel with their star points coupled, neutral-earth switchgear will be necessary and should be designed to provide the necessary isolation for generator maintenance purposes.

Where double-wound generator transformers are used in multiple LV generator installations, each generator LV installation can be treated as a separate electrical system and the combination is then treated as a high voltage generator. In this case, solid earthing of each generator star point, as if it were a single LV generator, provides an economic solution. Unrestricted earth fault protection, applied to the LV neutral-earth connection, will protect the generator, cables and transformer LV winding and will not be affected by the HV system configuration.

Where the transformers have similar ratings and impedances, it is usual to couple the HV star points and to earth these via a suitable impedance, sizes as described earlier. If the multiple generator transformers are not matched in terms of size and impedance, parallel operation may result in circulating currents and neutral-earth switching or the application of an earthing transformer to the high voltage busbar may be necessary.

e) Multiple generators operating as an alternative to an external supply

For high voltage generators, the HV system can be treated in the same manner as for the isolated case d) above, if care is taken to ensure that the generator system cannot become accidentally paralleled with the external system.

In the case of LV generator / transformer installations, the combination of each generator and transformer can again be likened to a high voltage generator. The LV system of each combination may be solidly earthed as before, since this is isolated from the external supply and earth fault protection applied as required.

f) Multiple generators operating in parallel with an external supply.

Multiple high voltage generators are **treated in the same manner as single HV generators when paralleled with an external supply.** The same considerations regarding operating generators with their star points coupled will apply.

In the case of generators that can be operated in parallel with their star points coupled, the common star point connection is taken to a neutral-earth switch and via the earthing impedance to the earth electrode.

Where the generators cannot be operated in parallel with their star points coupled, each generator must be provided with a neutral-earth switch that will be used to select the generator that is to provide the system reference when not in parallel with the external system. When the generators are in parallel with each other and with the external system, all neutral earth switches are open.

Generator/transformer combinations are treated in an identical manner with the star-point earth switch connected to all transformers in the case of operation with star points coupled and a separate earth switch for each transformer if this is not possible.

It is important to include automatic detection for incorrect operation of the earth reference switches as accidental operation with an unearthed neutral is potentially hazardous.

g) Mixed generation schemes where low voltage generators with transformers and high voltage generators operate in parallel.

These schemes will require special consideration, as the effective impedances of the generator combinations will be significantly different.

Generally, the most convenient treatment of these schemes is to avoid parallel operation with star-points coupled and to provide a neutral earthing transformer on the common busbar. This should be zigzag wound to attenuate third harmonic currents.

When a neutral earthing transformer is used on systems that parallel with an external supply, the star point earth is switched out when in parallel, in the same manner as for generators. Earthing impedances can be provided in the same manner as for generators and should be sized to take into account the impedance of the earthing transformer.

The circuit supplying the **earthing transformer should be protected in order to prevent hazard in the event of a winding fault.** However, this protection must intertrip with the generators to avoid the possibility of operating the system without a reference. Providing the transformer with a separate fuse-switch supply from the HV busbar will satisfy this requirement. Rupture of any of the fuses will cause an alarm contact to close, which can be used to trip the system.

Generator / transformer combinations for operation with an external supply

Where generator transformer combinations are used only for parallel operation with an external supply, as is common for combined heat and power applications, **significant savings may be made by use of a step-down configured transformer.**

In this case, a transformer with a delta wound high voltage and star wound low voltage windings is used to connect the generator to the system. The LV star point of the transformer is earthed and the generator phase conductors are connected to the transformer.

If phase-neutral synchronisation sensing is required, the generator and transformer neutrals may be linked.

The effect on the electrical system is to remove any contribution from the generator to system earth faults. The generator transformer is to a standard design and is usually available with a shorter lead time than its' step-up counterpart.

High voltage earth fault protection

Unrestricted and restricted earth fault protection may be applied to HV schemes in the same manner as for LV, as discussed earlier. **Unfortunately neither form of protection is sensitive to interturn nor phase-phase faults and so has limited application for large machines,** where repair or replacement costs may be high and down-time lengthy.

For many high voltage generators, the application of differential protection allows very low values of fault current in both the phase-earth and phase-phase paths to be detected and action taken immediately.

Differential protection relies on current transformers being positioned in the phase and neutral end of each winding to encompass a zone of protection. It is usual to include the cable connecting the generator to the high voltage switchgear within the protection zone and the high voltage switchgear is a convenient position for the phase-end current transformers. **The current transformers must be matched precisely for rating and magnetisation curve characteristic and it is usual for one manufacturer to produce all of the current transformers.**

Differential protection is generally the most stable form of protection under through-fault conditions (faults outside of the protection zone) even when set to very low current values and will allow indication of the affected phase.

References:

BS 7430:1998 – published by The British Standards Institution – ISBN 0-5802-8229-5.

BS 7671: 2000

Diesel Generator Handbook – LLJ Mahon – ISBN 0-7506-1147-2.

Safety should be the primary concern of the facility design engineer and all personnel engaged on installation and commissioning. Safety involves two aspects:

1) Safe access, egress and operation of the generator itself (and its accessories).
2) Reliable operation of the system.

Reliable operation of the system is related to safety because equipment affecting life and health, such as life support equipment in hospitals, emergency egress lighting, building ventilators, elevators and fire pumps, may depend on the generator set.

Fire Protection

The design, selection and installation of fire protection systems require the following considerations:

- The fire protection system must comply with the requirements of **National Standards** and of the authority having jurisdiction; who may be the building inspector, fire marshal or insurance carrier.
- Typically, the generator room will be required to have a one hour fire resistance rating if the generator set will be in at level 1 application. Generator room construction will have to have a two hour fire resistance rating.
- The generator room shall **NOT** be used for storage purposes.
- Generator rooms shall not be classified as hazardous locations solely by reason of the engine fuel.
- The authority will usually classify the engine as a heat appliance when use is for only brief, infrequent periods, even though the flue gas temperature may exceed 1000°F (538°C).
- The authority may specify the quantity, type and sizes of approved portable fire extinguishers required for the generator room.
- A manual emergency stop station outside the generator room or enclosure or remote from the generator set in an outside enclosure would facilitate shutting down the generator set in the event of a fire or another type of emergency.
- The authority may have more stringent restrictions on the amount of fuel that can be stored inside the building than published in national standard.
- Fuel tank construction, location, installation, venting, piping, and inspection inside buildings and above the lowest storey or basement should comply in accordance with National Standards.
- The generator set shall be exercised periodically as recommended under at least 30% load until it reaches stable operating temperatures and run under nearly full load at least once a year to prevent fuel from accumulating in the exhaust system.

Many national, state and local codes incorporate standards which are periodically updated, requiring continual review. Compliance with the applicable codes is the responsibility of the facility design engineer.

General

- Do **NOT** fill fuel tanks when the engine is running, unless tanks are located outside the generator room.
- Do **NOT** permit any flame, cigarette, pilot light, spark, arcing equipment, or other ignition source near the generating set or fuel tank or batteries.
- Fuel lines must be adequately secured and free of leaks. Fuel connection at the engine should be made with an approved flexible line.
- Be sure all fuel supplies have a positive shut-off valve.

Exhaust Gases

- Be sure the exhaust system will properly dispel discharged gases away from enclosed or sheltered areas and areas where individuals are likely to congregate. Visually and audibly inspect the exhaust for leaks as per the maintenance schedule. Ensure that exhaust manifolds are secured and not warped.
- **NEVER** connect the exhaust systems of two or more engines.
- **NEVER** discharge engine exhaust into a brick, tile or cement block chimney, or a similar structure. Exhaust pulsations could cause severe structural damage.
- Do **NOT** use exhaust gases to heat a compartment.
- Be sure that the unit is well ventilated.
- Shield or insulate exhaust pipes if there is a danger of personal contact or when routed through walls or near other combustible materials.
- **ENSURE** that there is independent support for the exhaust system. No strain should be imposed on the engine exhaust manifolds. Which is especially important on a turbocharged engine. Stress on a turbocharger could distort the housing, leading to failure.

Annunciation

Codes may require different levels of annunciation for critical life safety and all other emergency standby applications.

Moving Parts

- Tighten supports and clamps and keep guards in position over fans drive belts etc. Make sure that fasteners on the set are secure.
- Keep hands, clothing and jewellery away from moving parts.
- If adjustment must be made while the unit is running, use extreme caution around hot manifolds, moving parts, etc.

Hazardous Voltages

Electrical power generating, transmission and distribution systems will be required to comply with the applicable statutory regulations and approved codes of practice of the particular country of installation.

Codes of Practice

Approved Codes of Practice are usually generated by the Health and Safety Commissions, possibly in conjunction with industrial committees or with the British Standards Institution. Codes of Practice otherwise published by BSI or professional or trade bodies are classified as non approved codes. The BSI codes of Practice are supplemented by detailed specifications covering application and design of equipment, material and manufacturing standards.

Of the Codes and Standards prepared by professional institutions and trade associations perhaps the most important in our context, are the IEE Regulations for Electrical Installations (UK). Whilst they may not be legally enforceable they represent the best practice in electrical safety. Indeed, failure to the fundamental requirements contained in Part 1 of the Regulations could not lead to a an Electricity Supply Authority withholding a supply of energy to the installation.

Electrical Safety

Electrical installation must be carried out with care to avoid touching un-insulated live parts, especially inside the control panel box which can result in severe personal injury or death.

Improper wiring can cause fire or electrocution, resulting in severe personal injury or death and property or equipment damage.

For personal protection, stand on a dry wooden platform or rubber insulating mat, make sure clothing and shoes are dry, remove jewellery and use tools with insulated handles.

- Do **NOT** leave cables trailing on the engine room floor.
- Do **NOT** use the same trunking for electric cables and fuel or water lines
- Do **NOT** run AC and DC cables in the same looms or trunking
- **ALWAYS** ensure that bonding and equipment earthing are correctly done. All metallic parts that could become energised under abnormal conditions must be properly earthed.
- **ALWAYS** disconnect the batteries and battery charger when servicing or carrying out maintenance, particularly on equipment arranged for automatic mains failure operation. **ALWAYS** disconnect a battery charger from its AC source before disconnecting the battery cables. Otherwise, disconnecting the cables can result in voltage spikes high enough to damage the DC control circuit of the set. Accidental starting of the generator set while working on it can cause severe personal injury or death.
- Do **NOT** tamper with interlocks.
- **ALWAYS** follow all applicable state and local electrical codes. Have all electrical installations performed by a qualified licensed electrician.
- Do **NOT** connect the generator set directly to any building electrical system.
- Hazardous voltages can flow from the generator set utility line. This creates a potential for electrocution or property damage. Connect only through an approved isolation switch or an approved paralleling device.

High voltage sets require additional safety precautions. Special equipment and training is required to work around high voltage equipment. Operation and maintenance must be done only by persons trained and qualified to work on such devices. Improper use or procedures may well result in personal injury or death.

- Do **NOT** work on energised equipment. Unauthorised personnel must not be permitted near energised equipment. Due to the nature of high voltage electrical equipment induced voltage remains after the equipment is disconnected from the power source. Equipment should be de-energised and safely earthed.

Water

Water or moisture inside a generator increases the possibility of insulation breakdown and electrical shock, which can cause equipment damage and severe personal injury or death. Do not use a generator which is not dry inside and out. If a generator has been exposed to excessive moisture consult the operating manual before attempting to start the engine. If in doubt, have the generator Megger tested (insulation tested). Refer to service manual for minimum acceptable insulation resistance.

Coolants and Fuel

The coolant heater must not be operated while the cooling system is empty or when the engine is running or damage to the heater will occur.

Coolant under pressure has a higher boiling point than water.

- Do **NOT** open a radiator, heat exchanger or header tank pressure cap while the engine is running. Allow the generator set to cool and bleed the system pressure first.

Generating plants are used in three main duties:

1) **Primary or Base Load Duty**
2) **Peak Lopping Operation**
3) **Standby to Utility mode**

Load Characteristics

An overall assessment of load characteristics is necessary therefore the nature and characteristics of loads must be established, supported by analysed data. Installed equipment should be listed and duty cycles known.

The proposed method of plant operation should be known so that the load factor can be assessed and the demand deduced.

Where loads of different power factor are being considered, the active and reactive powers should be segregated, and then added separately. More accurate predictions can be made by applying diversity factors on both the reactive and active power.

The mode of operation of any motors requires to be established.

Generating capacity must be sufficient to meet peak power demand, even if the peak only occurs for a few hours once a year. Future load expansion should not be ignored, as there may well be a rise in energy requirements.

The timing of power plant additions must be carefully planned and expedited and extra capacity should be deferred until the need arises. Designs must be flexible enough to allow for planned expansion with the minimum of disruption to existing plant. It is usual to provide, at the outset, 10 to 20% margin of capacity over and above that required by the annual peak demand.

'Safe Generating Capacity' (SGC)

The SGC (safe generating capacity) = (installed capacity of station) - (capacity of largest machine) - (a further margin of 15% of the remaining installed generating plant). The SGC caters for system demand.

The latter margin allows for the site derating due to high ambient temperatures and low atmospheric pressures.

A typical **5MW** station with 5 x 1MW sets would have an SGC of:

(5) - (1) - (4 x 0.15) = 3.4MW

Definitions

Peak load is the maximum load or maximum demand during the period specified.

Utilisation factor the ratio of peak load to the plant capacity.

Average load is the average height of the load curve, given by;

$$\frac{\text{the total energy over a period}}{\text{the total hours in the period.}}$$

Capacity factor is the ratio of the average load to the plants total capacity. It is the measure of the actual energy supplied.

Load factor the measure of the plants utilisation, or the ratio of the energy units actually supplied in a given period.

The more usual way of expressing the load factor is to use the consumer's maximum demand (in kW or kVA) multiplied by the length of period in hours. The annual load factor (ALF) would then be given by:

$$\text{ALF}(\%) = \frac{\text{units* used in the period x 100}}{\text{Maximum Demand (MD) x 8760}}$$

(*the units would be in kWh, if the MD is in kW)

It is very unusual that individual consumers' MD's will coincide at any one time. The maximum demand on the plant will always be less than the sum of the MD's of the individual consumers.

The type and rating of generating plant must be dependent on the nature and size of the load it is required to serve.

- The element which require close tolerance parameters (computers and telecommunications)
- The element likely to change the load demand of the set or affecting transient performance, such as;
- step change loads or motor starting.
- non-linear loads.
- cyclically varying loads.
- regenerative loads.

Motor Starting

To accurately calculate the size of your generating set when the load consists of a number of electric motors, varying in size, possibly with different forms of starting methods plus a variety of resistive loads it is necessary to be very accurate to avoid undersizing your machine.

The effect of motors starting and start sequence should be determined in conjunction with the running loads so that the least size of genset can be selected to match the load profile. In certain circumstances, it may be more prudent to consider the miss-matching of engine and alternator to find the optimum solution.

Sizing

It should be noted that the largest motor may not necessarily have the largest impact on load, the impact being determined by the starting method.

The various normal starting methods, with their very generalised starting characteristics, are as follows:-

a)	Direct on line	7 x flc, 0.35 pf
b)	Star Delta	2.5 flc, 0.4 pf
c)	Auto transformer	4 x flc (75% tap), 0.4 pf
d)	Electronic Soft start	3 x flc, 0.35 pf
e)	Inverter Drive	1.25 flc, 0.8 pf
		(flc = full load current)

These figures are highly variable and specific data should always be obtained.

Particular care must be taken to ensure that:

1. **engines can develop sufficient kilowatts.**
2. **alternators can develop sufficient kVA.**
3. **frequency and voltage drops can be maintained within acceptable limits when the various loads are introduced.**

It is recommended that the client, or his consultant, be contacted to discuss the load profile, particularly in cases where worst case loading (i.e. the most onerous impact load starting with all other loads connected) provides a less economical solution in terms of capital cost of equipment. A better solution may be achievable by re-arranging the profile.

- To size the generating sets once the optimum sequence of operation has been determined.

Voltage Dip

Voltage dip is largely independent of the load already carried by the generator, particularly if this is a mixed passive load, but any motors running on the system at the time will experience a speed change, which will cause them to draw more current. This increased load current, when added to the starting current of the starting motors causes the voltage dip to exceed its expected value.

The magnitude of the voltage dip at the generators terminals, following load switching, is a direct function of the subtransient and transient reactances of the machine.

Dip, V = X'du (X'du + C)

Where X'du is the per unit unsaturated transient reactance and C is the ratio:

$$\frac{\text{generator rating (kVA or current)}}{\text{impact load (kVA or current)}}$$

Limiting Voltage Dip

The voltage dip on a machine can be limited in a number of ways:

1. Where a number of motors constitute a major part of the load, it may be feasible to limit the starting sequences of the motors minimising the impact load.
2. The motors with the largest load should be run up first.
3. A generator of low transient reactance may be used, this can be achieved by using a larger frame size machine.

Power Factor Correction

When the load current and voltages are out of phase due to the load not being purely resistive, defined as lagging and leading loads, no single angle can be used to derive the power factor.

The methods used for power factor correction are:

1) Synchronous motors (driving pumps, fans, compressors, etc. with their working power factor adjusted, through excitation control, to give operation at unity or leading power factor. The motors will only contribute to power factor correction whilst they are running.

2) Synchronous condensers, which are effectively synchronous motors used solely for power factor correction and voltage regulation.

Capacitors

By individual correction using capacitors directly connected to the supply terminals of individual, low power factor items of plant.

By using manually controlled capacitors, located at key points within the plant, and switched in when the appropriate sections of plant are in operation.

Automatically controlled capacitors switched in and out of circuit by contactors as the load varies.

Power factor correction capacitors operate at almost zero power factor leading and are used to correct the overall lagging power factor of a complete installation to a value approaching unity power factor but still lagging.

Unusual Loads

Non-linear Loads

The use of solid state power devices such as thyristers and triacs are major sources of harmonic distortion in supply networks. The non linear load currents that characterise such equipment may well be within acceptable limits, where the power source is a low impedance public utility supply, but if a converter is used in the installation the non linear loads will be more significant and less predictable. The harmonic currents generated will depend upon the type of converter used, whereas the resulting voltage harmonics will relate to the property supply network.

To suppress harmonic distortion the following methods can be used;

Filter banks: their design requires considerations of the load duty cycle and knowledge of the impedances, to avoid them acting as sinks for harmonics generated elsewhere.

- Grouping the converters to form a single unit.
- Phase shifting; with the use of special rectifier transformers which alter the phasing of the secondary winding or the angle at which the harmonics are produced.
- Reduction of the supply system impedance: by increasing the frame size of the alternator or using a specially designed low-reactance machine.

Fluorescent Lights

At ‘switch on’, fluorescent lights produce high transient terminal voltages, as a purely capacitive load is present without any appreciable level of active load. The power factor correction capacitors of fluorescent lamp installations can have the effect of imposing high transient stresses on the rotating diodes of the brushless alternator. A non inductive and matched resistance in parallel with the main field offers a solution to the problem.

Lifts and Cranes

Mechanical energy may be fed back to the power source in the form of electrical energy when braking lifts and cranes. This energy may be absorbed by the other equipment operating, but the surplus power will cause the generator to act as a motor, tending to drive its prime mover. The generator speed will increase and the governor will reduce its fuel supply. The reverse power must be totally absorbed by the mechanical losses and the generators electrical losses. However the generator is capable of absorbing limited regenerative power (<10% rating) capability so if regenerated load is connected to the generator, the total of the other load elements should be equal to the regenerated power. It may also be necessary to connect a continuously rated resistive load to absorb the regenerated power, such as load banks.

Capacitive Loads

As the capacitive load increases, there is a tendency to over excite the generator. The effect of capacitive loads, produces a high terminal voltage, limited by the magnetic saturation of the machine. The terminal voltage is determined by the intersection of an impedance line with the open-circuit magnetisation characteristic of the generator. There must be a limit to the amount of capacitance that can be switched onto the generator if voltage stability is to be maintained. A non inductive and matched resistance in parallel with the main field resolves this problem as such loads will tend to increase the main and excitor field currents and oppose the self exciting effects of the capacitive load element.

The limitation on capacitive load level is approximately 0.93 pf lead under all load conditions.

Unbalanced Loads

Ensure that single phase loads are evenly spread across all phases.

Unbalanced currents caused by faults other than those involving all three phases can occur. Faults are usually cleared by circuit protection, any failure of the remote protection to operate or related circuit breakers to trip would result in the fault circuit remaining connected to the generator. Action should be taken to trip the generator breaker if the unbalanced condition persists or if the level of the negative phase sequence current rises. The alternator manufacturer’s literature should be consulted for the level settings of the fault circuits.

Suggested Maintenance Schedule

Check Sheet – Emergency standby generators

Used for guidance only – always check manufacturers recommendations.

			10 hrs/ Weekly	100 hrs/ Monthly	200 hrs/ Yearly
1 Engine	1.1	Check lubricating oil level	x		
	1.2	Change lubricating oil			x
	1.3	Check fuel tank level	x		
	1.4	Check water coolant level	x		
	1.5	Check anti-freeze content in cooling system and change DCA filter		6 monthly	x
	1.6	Check vee belt tension			x
	1.7	Clean air filter or if oil bath type check level			x
	1.8	Check all fuel, exhaust, air piping for leaks			x
	1.9	Drain sediment from fuel tank		x	
	1.10	Check fuel tank breather		x	
2 Engine Electrics	2.1	Check electrolyte level in battery	x		
	2.2	Check state of charge with hydrometer		x	
	2.3	Clean cable terminations on battery and regrease			x
	2.4	Check fuel solenoid is operating correctly		x	
	2.5	Check auxiliary terminal box connections	x		
3 Generator	3.1	Clean apertures and internally with a dry air supply		x	
	3.2	Grease bearings (if required)			x
	3.3	Check ventilation areas for obstructions	x		
4 Switchgear	4.1	Check functioning of all relays			x
	4.2	Check functioning of all switches (including engine)			x
	4.3	Check that contacts of circuit breakers and contactors are clean			x
	4.4	Check condition and rating of fuses and tripping devices			x
5 General	5.1	Check and tighten all nuts and bolts (as required)			x
	5.2	Check condition of anti-vibration mountings (if fitted)			x
6 Complete Set	6.1	Run set for one hour minimum preferably on 50 per cent load	x		
		Check and Note: 1 Approximate starting time 2 That all engine instruments are functioning 3 That all switchgear meters are functioning 4 All lamps are operating correctly 5 All switches are functioning			
	6.2	Clean complete set and exterior of panel and remove dust			x
7	7.1	Have generating set inspected by manufacturer			x

Regular Maintenance

Most owners of standby sets ensure that they are completely and regularly maintained. There are, however, other operators who ignore maintenance and when there is a power shutdown, the set does not always start. In most of these instances, faulty starting and control systems are blamed, but over the years, the real villain is neglect of regular preventive maintenance. This neglect can be expensive and can endanger life.

Preventive maintenance is the easiest and most inexpensive form of maintenance since it permits staff to carry out the work at convenient times. It starts with a well prepared schedule. This should be established according to the duties expected of the generating set, since while most sets are only used for short periods, "in anger", there are others used for load shedding, which have higher working periods.

Regular checking

Generally, a standby set should be checked weekly and run for a short period, preferably on load, to exercise both the engine/alternator and its control panel. All information and readings should be logged. The suggested schedule check sheet may be used as a guide to establish a maintenance programme to fit any specific operation. It is assumed that the set has been commissioned and that the initial running in instructions have been carried out by a properly trained maintenance Dept, who should supplement these with any other particular operation that may be listed in the generating sets engine manual. The time between checks could vary depending upon site conditions, e.g. high dust laden atmosphere, which the maintenance schedule should take into account.

At some installations, there may be no properly trained maintenance staff to carry out this work in which case it is advisable to enter into a regular maintenance contract with the supplier.

A maintenance contract can take the form of a simple signed agreement between the owners of the generating set and the set manufacturer or its representative. The owner being referred to as the "user", the manufacturer as "The contractor". It would be expected that the maintenance contract would include clauses covering:

1. That the user only utilises experienced and trained operators.
2. An agreed time between visits.
3. Exact details of work to be carried out.
4. The contractor to replace any parts recommended by the user not covered by the guarantee or maintenance schedule.
5. The contractor to undertake arrangements for major engine overhauls that may be needed from time to time.
6. An agreed period for work laid down in the maintenance schedule (it is usual to add the cost of parts used during the execution of the schedule).
7. The user to provide all necessary facilities to enable the contractor to carry out the execution of the schedule during normal workday hours.
8. Indemnification of the contractor against loss or damage to property or injury to personnel arising directly or indirectly in the performance of the service.
9. Notice of termination of the contract by either party. To avoid any contention that may arise as a result of any misunderstanding or obligation it is advisable to have a formal, legalised agreement drawn up.

The basic maintenance schedule normally covers the following services:

(a) Check condition of air cleaners, fuel oil filter elements and lubricating oil filter elements, change if necessary.

(b) Check coolant level, leaks, anti-freeze strength and DCA content where applicable.

(c) Check lubricating oil level and leaks and top up or change if necessary.

(d) Check fuel oil levels and leaks.

(e) Check fuel injectors (visual only).

(f) Check fan belt condition and tension correct if necessary.

(g) Check starter battery condition, voltage and specific gravity of electrolyte and level.

(h) Check alternator brushes if applicable, replace as necessary.

(i) Check condition of switchboard lamps, fuses, meter, contactors and other switches.

(j) Check output of battery charger if applicable.

(k) Check for loose electrical and mechanical connections, tighten as necessary.

(l) Check regulation of alternator voltage and frequency.

(m) Simulate "mains failure" operation if applicable.

(n) Submit report to customer on condition and state of plant. The most common cause of an engine failing to start is badly charged batteries.

Batteries

Invariably batteries are either under-charged or over-charged, the latter being more common and causing a deterioration in the battery's life.

It is essential that special attention is given to batteries to ensure that they are always in a near fully charged condition at possible and regular readings are taken of their specific gravity. The misuse of battery chargers is normally found to be the cause of over-charging.

During the starting cycle of an engine the voltage of the battery drops to its lowest value and the current drawn is at its highest level directly the starting switch is operated.

Immediately the motor turns or "breaks away" the current falls off with the voltage rising. It is at the initial critical moment of operating the starting switch that essential components such as fuel cut off solenoids and relays are required to operate. Although some manufacturers arrange their circuits to avoid this situation, by slightly delaying the operation of the starter motor, there are many sets where these two operations are carried out simultaneously. It is therefore absolutely vital that the battery is in peak condition.

Light Loads

A fault that occurs quite frequently even when maintenance is carried out regularly, is the engine injectors fouling due to excessive light load running. As will be seen from the typical maintenance schedule, a figure of 50 per cent loading is mentioned. The load factor should be considered as a minimum and a full load factor would be more desirable, followed by 110 per cent load for a short period.

With this load factor it does ensure that the engine does not suffer from injectors being "clogged with carbon deposits due to unburnt fuel. Also, running on a light load will in time dilute the engine lubricating oil. Obviously there are many causes of a set failing to start or failing to operate correctly. Preventive or planned maintenance is not a panacea for malfunctioning, but it will go a long way to avoid the non-starting of the set when it is most needed.

Enclosed Soundproof Generating Sets

The choice of reducing sound levels on generating sets falls into a number of categories.

Standard Sheet Metal Weather Protection – For use outdoors, small reduction on mechanical noise, but radiator noise is unaffected. Exhaust noise can be reduced with residential silencers.

Enclosing the Generator in a Specially Designed Sound Proof Canopy with air inlet and outlet sound attenuators – for use outdoors.

Standard soundproof enclosures will give a reduction between 15 and 30 dBA. A further reduction can be achieved by increasing the density of the barrier and increasing the length of air inlet and outlet attenuator on specially designed enclosures for specific duties.

Installing the Generating Set in a Normal Brick Room with air inlet and outlet sound attenuators and acoustic doors. High reverberant noise level within the plant room but effective reduction of the noise levels to outside.

Installing the Generating Set in a Room Lined with Sound Absorbing Material and with air inlet and outlet sound attenuators.

Noise inside plant room reduced and considerable reduction on noise level to outside.

Installing an Enclosed Generating Set in a Room.

The set is enclosed in a specially designed sound proof canopy with integral air inlet and outlet sound attenuators.

Low noise levels inside and outside of room.

Other Means of Reducing Noise.

The use of remote radiators (to spread the noise over selected areas) and the use of cooling towers, although in both cases the generating set noise, even without the radiator will be relatively high.

Definitions:

Weatherprotected

Sheetmetal enclosure with side doors for accessibility and silencers mounted inside or on roof. Small amount of soundproofing but lowest cost weather protection.

Silenced

Noise level 85dB(A) @ 1 metre distance from enclosure. This is the average noise level recorded at multiple points around the enclosure with the genset operating at 75% prime rating.

The Noise Directive

To meet noise regulation 2000/14/EC sets will be tested according to EN ISO 3744:1995 which is the industry standard effective from 3 January 2002 for generators below 500 kVA (400 kW) for use in the EEA.

Measurement Methods

Multi-point positions around the generator (Fig. F1) are established in cubical square volumes of space. This pattern is known as parallel piped configurations and used to record decibel sound levels.

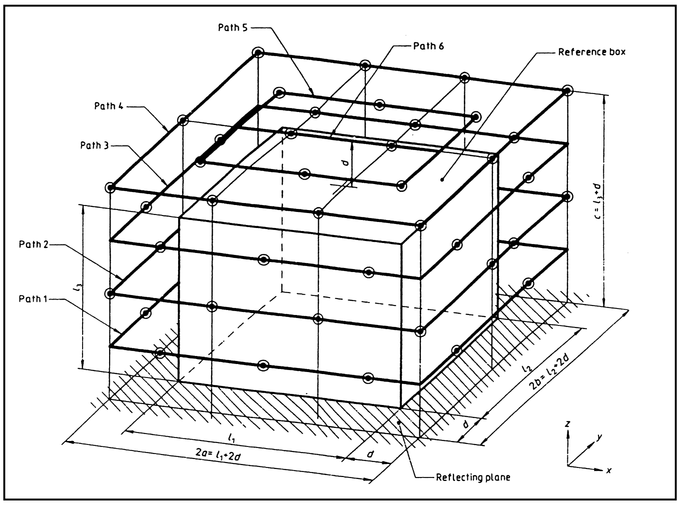


Fig. F1 Example of a measurement surface and microphone positions (paths) for a large machine.

Above 400 kW (500 kVA) the hemispherical multi-point position (Fig. F3) of decibel readings are used for testing and establishing sound levels through the octave band frequencies.

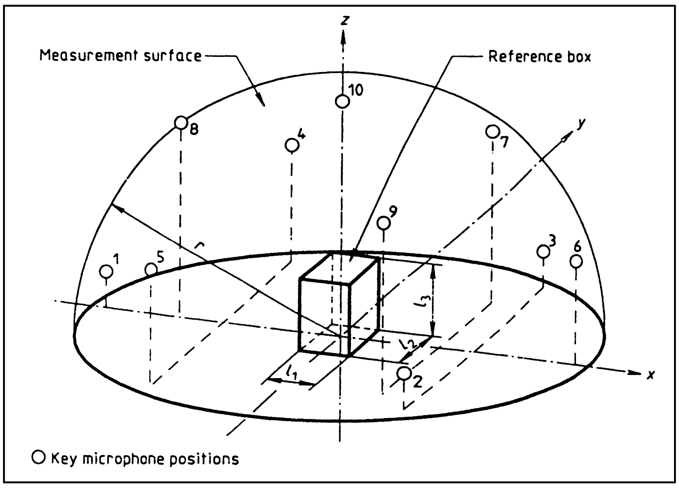


Fig. F2 Microphone array on the hemisphere – key microphone positions.

Super Silenced

Noise level 75dba @ 1 metre distance from enclosure. This is the average noise level recorded at numerous points around the enclosure with the genset operating at 75% prime rating.

Self Contained and Close Fit Enclosures

Compact and HD range from 32 kVA to 511 kVA (Fig. F5)

Standard Genset housed within a soundproof enclosure with an under-frame incorporating a lifting facility enabling a single unit lift. A daily service fuel tank is also housed within the enclosures.

The enclosure sizes are kept to a minimum. Service and maintenance is carried out through a number of access doors. The genset controls are accessed from outside the unit.

ISO Container Silenced Enclosures of Sets Above 600 kVA

In 6m (20 ft), lengths and 12m (40 ft) sizes. Silenced and self contained. See below for standard dimensions.

	Length (mm)	Width (mm)	Height (mm)
20 ft Standard Container	6058	2438	2591
20 ft ‘High-Cube’ Container	6058	2438	2895
40 ft Standard Container	12192	2438	2591
40 ft ‘High-Cube’ Container	12192	2438	2895

Description

Silencing and weather protection of generating sets is accomplished in a wide variety of applications with a range of enclosures.

Weatherprotected

Where sound levels are not critical, the “totally enclosed” style, weatherprotected enclosure, suitable for site operation, mobile work and emergency duties, can be provided. Designed for Generating Sets from 32 to 230kVA, these enclosures fit on to a baseframe to form a compact unit providing accessibility to fuel, oil and water servicing points for maintenance and operation.

Each enclosure has wide hinged and lockable side doors. These enclosures allow Generating Sets to be run with all doors closed. Silencers are mounted internally or on the roof.

A base fuel tank is normally incorporated in the chassis of the generating Set.

Above 250kVA with NTA855 engines and upwards, weather protected enclosures are provided as ISO non-silenced containers of 6m (20ft) and upwards in length.

Silenced and Supersilenced (Fig. F3 and Fig. F5)

Acoustic enclosures are designed to reduce noise emitted from a Generating Set. A range of types provide noise reductions from 15dB(A) to 30dB(A) meeting EC2000/14, 2002 and 2006 regulations where applicable.

Air inlet and discharge flows are through sound attenuators positioned at each end and constructed in splitter or baffle form to achieve effective noise absorption with minimum air resistance. Each sound attenuator incorporates fixed blade weather louvres and bird guards.

Each enclosure has hinged and lockable doors each side providing excellent accessibility to all servicing points.

Residential silencers are installed internally. Internal pipework is lagged with a heat and sound resistant material.

All enclosures have four lifting points to allow for lifting of both the enclosure and Generating Set. All units are totally self contained with base fuel tanks, batteries, exhaust system and control panel.

Containerised Style (Fig. F4)

For packaged and portable style Generating Sets, container acoustic sound-proofed enclosures can be provided. These are available for generating Sets from 700 kVA to 2000 kVA. Generating Sets are accommodated within standard ISO containers.

Air inlet and discharge flows are through sound attenuators positioned at each end of the container and constructed in splitter or baffle form to achieve effective noise absorption with minimum air resistance. Each sound attenuator incorporates fixed blade weather louvres and bird guards.

The exhaust system employs residential silencers with pipework lagged inside the container.

All containers incorporate personnel access doors, generally with one single door on each side. These have a peripheral compression seal and are fitted with either a heavy-duty single-point handle and fastener or an espagnolette fastener. An internal panic release mechanism is fitted and all doors are lockable.

Four-point lifting is provided.

A cable gland plate is fitted on the output side.

Containerised power plant complying to EC2000/14 and are produced for Generating Sets up to 2000 kVA.

Installation of Enclosed / Silenced Sets

Positioning

Select a position for the enclosed generator which should be as close as possible to the load to be supplied, ensuring that the following conditions are met:

The ground must be dry, level and firm enough to support the weight of the enclosure without any sinking with time.

The positioning of the enclosured generator should be such that generator exhaust and cooling air flows do not create a nuisance, or potential source of danger to personnel, or buildings etc.

There must be adequate access for installation and commissioning of the generator. Also allowance must be made for maintenance including:

- Inspection of door seals and door hinges, door handles, locks, and internal panic-release mechanisms for correct operation.
- Inspection of air inlet and outlet ventilation grilles for clogging by debris, and obstruction by objects.
- Inspection of exhaust system for leaks and damage, and that no materials or debris can come into contact with the hot exhaust system.
- Inspection of exhaust pipe exit for obstruction.
- Inspection of external surfaces for damage periodically, with periodic cleaning where required.
- Auxiliary supply requirements for standby sets.
- Cable routes.
- Fuel storage and refuelling access.

Fig. F3 Silenced enclosure for 500 kVA meets 75dB(A) @ 1 m.

Preparing for Installation

Prepare for installation as follows:

- Position the enclosured generating set in the required place.
- Open the canopy doors and carry out the full installation procedure as described in the Generator manual.
- Carry out generator commissioning as described in the Control System manual.

Caution:

Plugs / wiring of adequate current, voltage and insulation rating must be used.

Caution:

All non-current carrying metalwork associated with the equipment must be bonded to a suitable earth connection.

Container range accommodates sets from 750 kVA upwards. (Fig. F4)

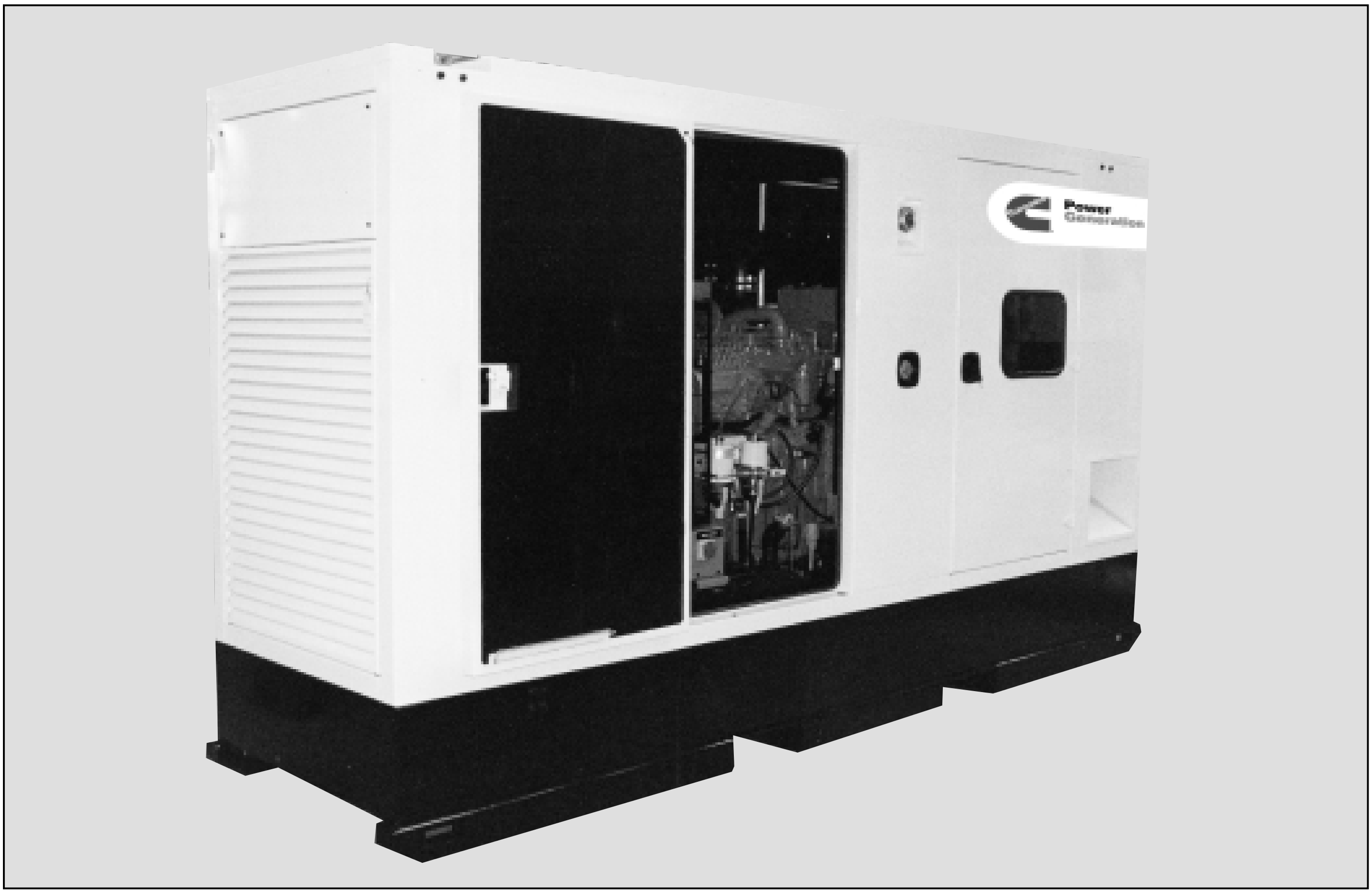


Fig. F5 Packaged Super silenced 100 kVA Generator

Fig. F6 Super silenced ISO 12m containerised unit will accommodate sets from 1200 to 2000 kVA.

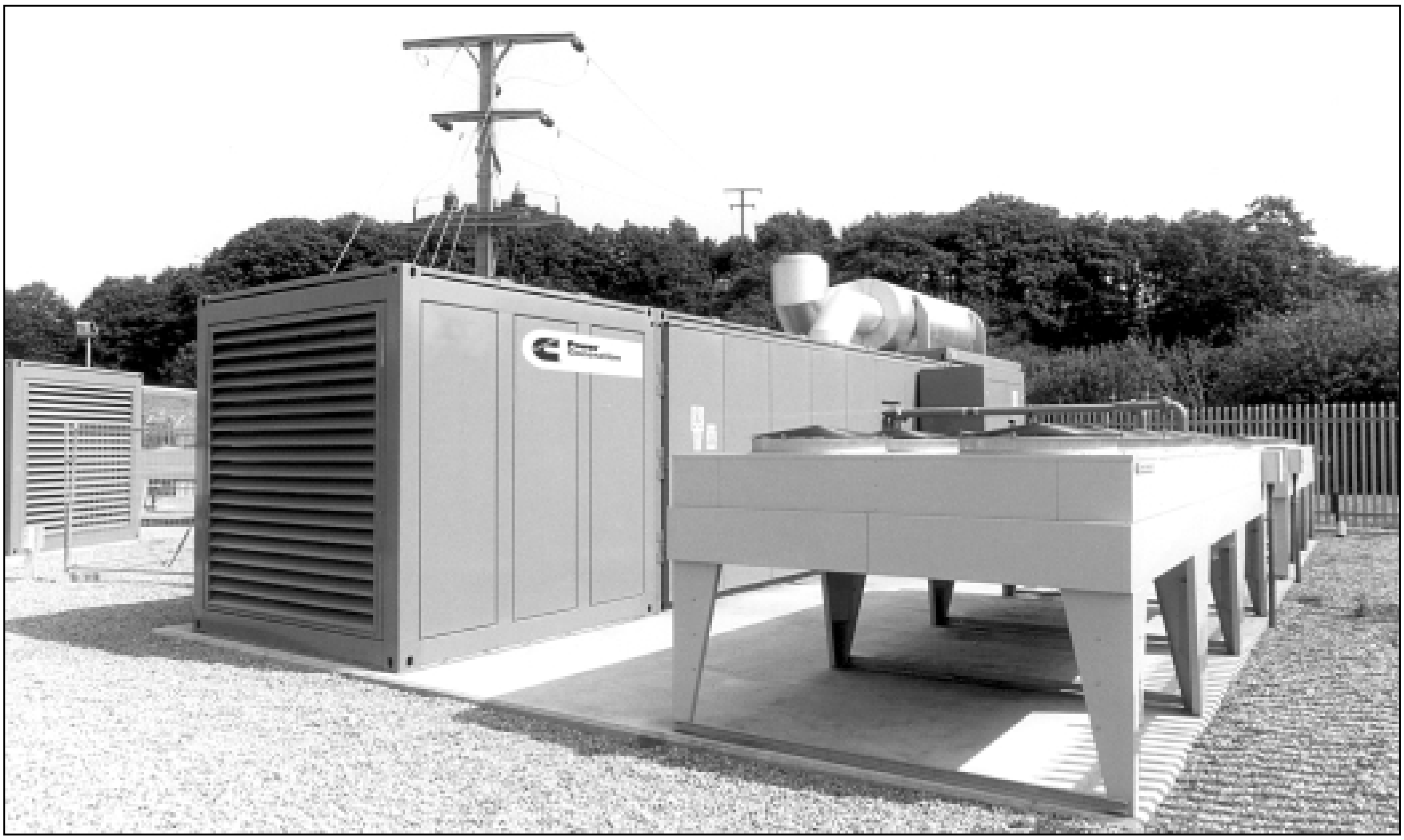
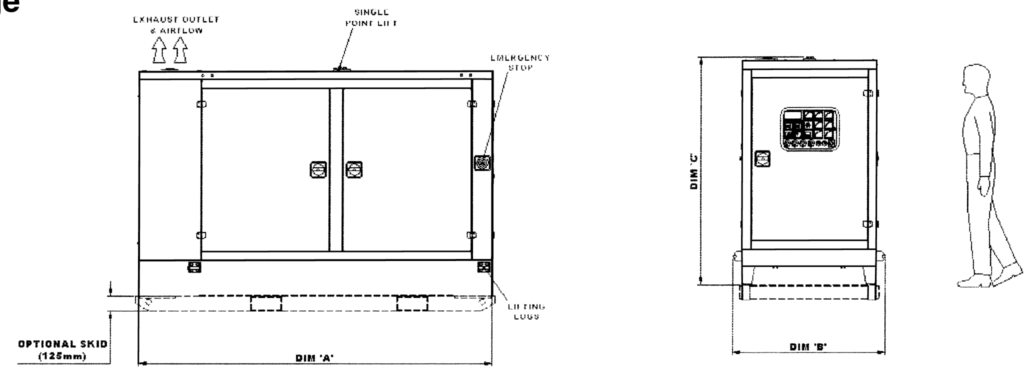


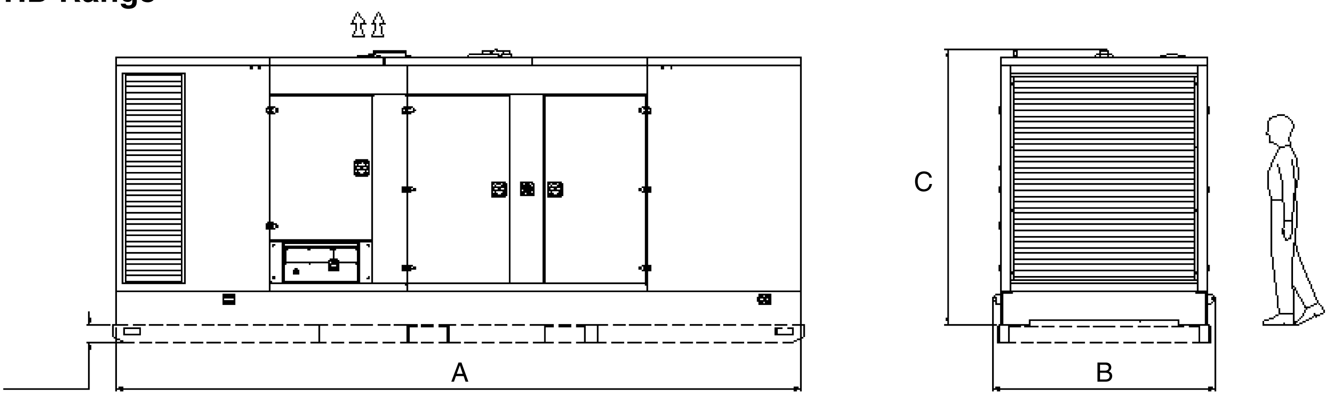
Fig. F7 Example of containerised style silenced enclosure for generators up to 2000 kVA

Compact Range



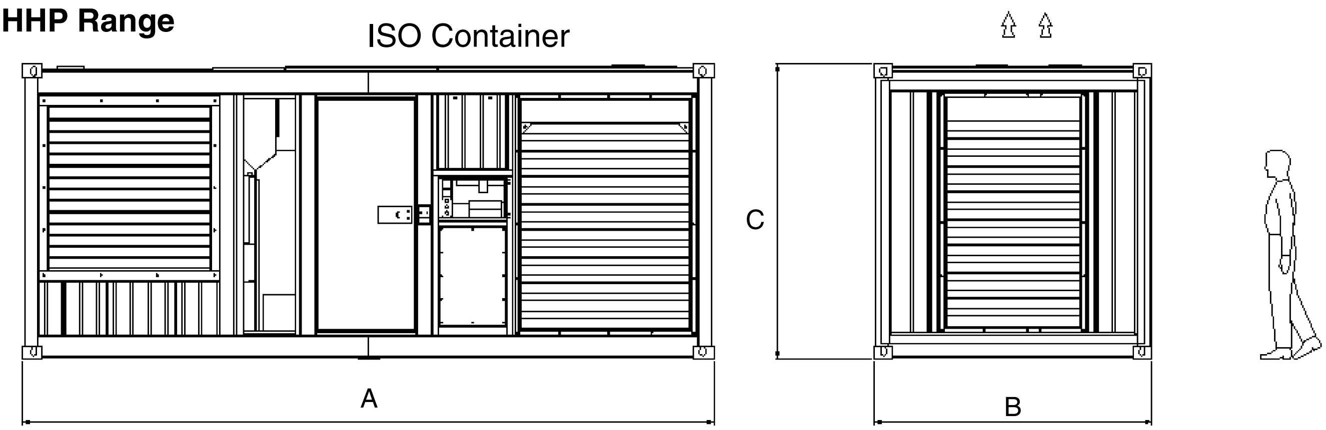
For Sets
32 kVA to 230 kVA with B3.3, 4B, 6B and 6C engines.

HD Range



For Sets
233 kVA to 511 kVA with LTA10, NT855, QSX15 and K19 engines.

HHP Range



For Sets
575 kVA to 2000 kVA with VTA28, QST30, KTA50 and QSK60 engines.

Note: All dimensions and weights are intended as an approximate guide only. Always ask for certified drawings once a project proceeds.

Silenced 85dB(A) @ 1m
Supersilenced 75dB(A) @ 1m

Fig. F8 Silenced enclosures.

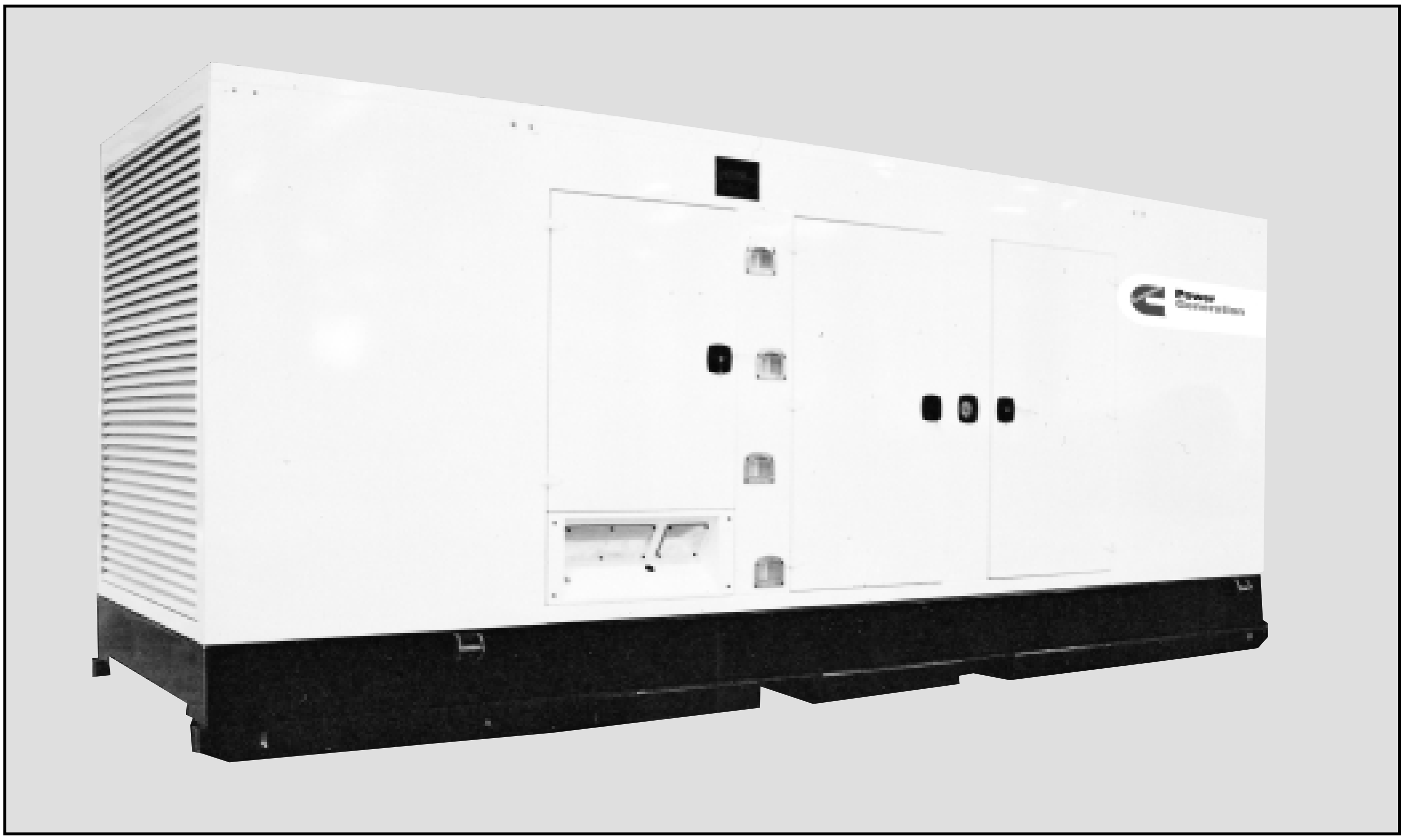


Fig. F9 ‘Heavy duty’ silenced genserator.

Main Sources of Noise

Generator noise falls into three main categories -

- airborne noise from the engine itself (typically 100-110 dBA at 1 m)
- engine exhaust noise (typically 120-130 dBA at 1 m, unsilenced)
- radiator fan noise (where applicable) (typically 100-105 dBA at 1 m)

Although the alternator itself is also a noise source, levels are typically 15-20 dBA below engine noise levels, and are thus normally not significant.

Where set mounted or local motor driven radiators are involved it is important to recognise the significance of the radiator fan as a noise source. This is particularly the case now that 'high duct allowance' radiator fans are increasingly used to reduce the size and cost of ventilation/attenuation systems.

Whilst looking at noise levels, it is worth noting that noise is not particularly sensitive to the size of the generator set - for the output range of 100-2000 kVA, for example, typically airborne engine noise levels may only vary by up to 15 dB (i.e. 100-115 dBA).

Noise + Ventilation

The main problem with generator noise control is not the noise control per se, but the **combination** of noise control and ventilation requirements.

Diesel generator sets radiate significant amounts of heat and whether directly radiator cooled, remote radiator, or heat exchanger cooled - significant air quantities are required for cooling (e.g. 15-20m^3/s for a 1000 kVA set). This, when compared with noise control requirements, involves significant space for the equipment involved - and space is invariably at a premium.

Standards/Spec. Levels

Such National / European Community standards specific to generator sets as exist or are envisaged relate more to noise exposure from a health and safety aspect than to 'comfort' levels. Whilst for most sets this involves some degree of noise control (typically around 85 dBA at 1m), 'comfort' levels associated with the surrounding environment into which the generator is to be introduced generally result in more stringent noise levels. In many cases theses levels are stipulated by Local Authority Environmental Health Departments as part of the planning conditions, and relate to Environmental Legislation (the Environmental Protection Act etc.).

These levels will often relate to existing background noise levels in the area (e.g. at nearby residences, offices, hospitals etc.). Whilst some relaxation may be tolerated due to the standby nature of most generators, this would typically only be +5 dBA on levels specified for continuous running plant.

Some account will be taken, however, of likely times of operation (i.e. night-time levels will generally have to be significantly lower than daytime levels).

Noise levels are still most common expressed in 'dBA' requirements. The 'A' weighting essentially relates to the response of the human ear (i.e. less sensitive to low frequency noise). Environmental noise is often expressed in time weighted averaged (e.g. Lgo, Leq), but for test purposes a generator would effectively be taken as continuous running.

Sometimes noise levels are specified in 'NC' or 'NR' terms (sound pressure levels). These relate to standard curves (See Table 1) which must not be exceeded in any particular octave band (unlike the 'dBA' figure, which is an overall level).

As a rough guide, dBA can be related to NC/NR levels using the following relationship:

NC/NR +5 ≈ dB(A)

E.G. NR40 ≈ 45 dBA

It is important when relating to specified levels that the **distance/position** at which that level applies is clarified.

EC Directive 2000/14/EC which specifically applies to the generator sets used on construction sites is widely used as a base standard for noise levels in the absence of overriding environmental requirements. The specification uses sound **power** level rather than **pressure** level as a unit (the intention being that the measure is independent of the environment in which the plant is used - a common analogy is that a 2kW electric fire will not tell you the temperature a space will reach unless you know the details about that space).

Currently (for sets above 2 kVA) the figure is 100 dBA sound **power** level, which **broadly** relates to 83-85 dBA @1M sound **pressure** level (depending on the physical size of the set). However, the Directive is currently under review, and it is anticipated that these levels will drop by 3 dB.

Fig. F10 Drop over super silenced enclosure for 2 x 1000 kVA standby generators.

Table 1

Noise Rating – NR LEVELS (Sound Pressure Level) OCTAVE BAND CENTRE FREQUENCY (Hz)								
	63	125	250	500	1K	2K	4K	8K
NR100	125	119	105	102	100	98	96	95
NR 95	111	105	100	97	95	93	91	90
NR 90	107	100	96	92	90	88	86	85
NR 85	103	96	91	87	85	83	81	80
NR 80	99	91	86	82	80	78	76	74
NR 75	95	87	82	78	75	73	71	69
NR 70	91	83	77	73	70	68	66	64
NR 65	87	78	72	68	65	62	61	59
NR 60	83	74	68	63	60	57	55	54
NR 55	79	70	63	58	55	52	50	49
NR 50	75	65	59	53	50	47	45	43
NR 45	71	61	54	48	45	42	40	38
NR 40	67	57	49	44	40	37	35	33
NR 35	63	52	45	39	35	32	30	28
NR 30	59	48	40	34	30	27	25	23
NR 25	55	44	35	29	25	22	20	18
NR 20	51	39	31	24	20	17	14	13
NR 15	47	35	26	19	15	12	9	7
NR 10	43	31	21	15	10	7	4	2

Noise Criteria –NC LEVELS (Sound Pressure Level) OCTAVE BAND CENTRE FREQUENCY (Hz)								
	63	125	250	500	1K	2K	4K	8K
NC 70	83	79	75	72	71	70	69	68
NC 65	80	75	71	68	66	64	63	62
NC 60	77	71	67	63	61	59	58	57
NC 55	74	67	62	58	56	54	53	52
NC 50	71	64	58	54	51	49	48	47
NC 45	67	60	54	49	46	44	43	42
NC 40	64	57	50	45	41	39	38	37
NC 35	60	52	45	40	36	34	33	32
NC 30	57	48	41	35	31	29	28	27
NC 25	54	44	37	31	27	24	22	21
NC 20	51	40	33	26	22	19	17	16
NC 15	47	38	29	22	17	14	12	11

Table 2 shows the typical ambient levels for both day time and night time in central London, suburban and country conditions.

Group	Location	Noise Climate dB(A) 08.00-18.00h	Noise Climate dB(A) 01.00-06.00h
A	Arterial roads with many heavy vehicles and buses (kerbside).	80-68	68-50
B	i) Major roads with heavy traffic and buses. ii) Side roads within 15-20m of a road in group A or B(I)	75-63	61-48
C	i) Main residential roads ii) Side roads within 20-50m of heavy traffic routes iii) Courtyards of blocks of flats screened from direct view of heavy traffic.	70-60	54-44
D	Residential roads with local traffic only.	65-57	52-44
E	i) Minor roads ii) Gardens of houses with traffic routes more than 100m distant	60-52	48-43
F	Parks courtyards and gardens in residential areas well away from traffic routes	55-50	46-41
G	Places of few local noises and only very distant traffic noise	50-47	43-40

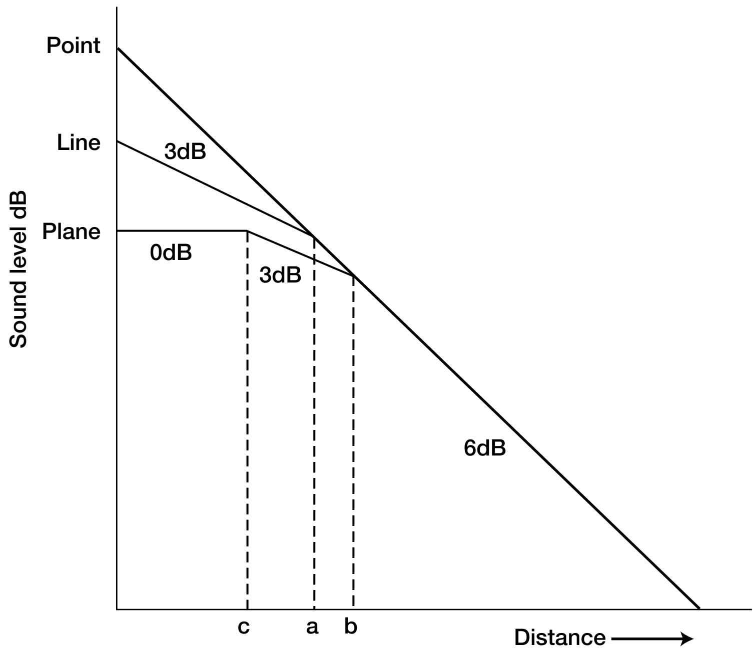


Fig. F11 Attenuation with distance from various sources
The slope represents 0.3 and 6dB per doubling of distance

Noise Legislation

Noise legislation relating to generators exists throughout the EEC. 2000/14/EC.

For other countries check local regulations and standards.

Typical Noise 'Climates'

Where a noise level is not specified, but it is felt that some attenuation may be required, an assessment of a desirable level can be made by relating to the prevailing background noise (this is broadly what current UK environmental legislation does). It is important to recognise that background noise would **not** generally include noise 'peaks' from (e.g.) passing traffic, trains or planes. More distant (e.g. motorway) traffic noise may be relevant if it effectively represents a more continuous type of noise. Table 2 indicates some typical ambient noise levels, and also shows the variation between daytime and night-time.

As a **rough guide** (in the absence of other specified levels) **standby** generator noise should equal or be up to 5 dBA less than the background noise at the **most likely noise sensitive points**. Note that peak lopping, CHP, landfill gas and other 'non-standby' sets will generally need designing to a lower level dependant on times of operation.

Relating the Specification Level to Generator Noise

Having been given or estimated a spec. level it is important - as stated earlier - to establish **where** these level(s) apply - at what distance(s) and position(s) in relation to the generator set. If there is a choice in the siting of the set this can have a significant effect on the attenuation required. If, for example, the level applies at a particular boundary then siting the generator remotely from that boundary will allow distance attenuation to assist in establishing a more realistically achievable noise level at the set position.

Similarly, the effect on any building(s)/topography on site between the generator position and spec. point should be considered. The resultant 'screening' attenuation can be valuable in assisting to achieve the spec. level required.

It is important that such factors are taken into account when specifying generator noise levels - often the latter are presented in terms of a level at 1 m from the set/package/plant-room **without** allowing for 'natural' attenuation. The resultant spec. level - apart from being unrealistic - can often be very costly (if it is not impossible) to achieve.

In most situations the main 'natural' attenuation available is that due to distance (as the sound waves radiate further from the source the radiating area increases and so sound pressure level reduces). Whilst the commonly used formula for distance attenuation is "6 dB drop with doubling of distance" this **must be used with caution**. This is because the formula relates to radiation from a point source. At closer distances a generator set (whether enclosed or via plant room louvres) effectively represents a plane source. Nearer a **plane** source the reduction from attenuation due to distance is **considerably less** than for a point source. (See figure F11.)

The following corrections should be used as an **approximate guide** for attenuation due to distance.

Up to 10m 1 dB per meter
(i.e. 5m = -5 dB, 10m = -10 dB etc.)

Above 10m apply 6 dB per doubling of distance,
i.e. 20m = -16 dB, 40m = -22 dB etc.

The following table summarises the attenuation due to distance:

Distance (m)	Attenuation (dB)
1	-1
3	-3
5	-5
7	-7
10	-10
15	-13
20	-16
30	-19
40	-22
50	-23
100	-29

Also see Page F10.

Application Notes

Outdoor locations, acoustically enclosed

In this situation the acoustic enclosure performs two main functions - providing a secure weatherproof housing for the generator, and the required level of attenuation.

The enclosure and its ancillaries can take various forms, but all contain a number of key features:

- The enclosure itself. Typically a one piece 'drop over' style unit with access doors as appropriate or a self contained package unit.
- The attenuated ventilation system, comprising inlet and outlet louvres/attenuators, with dampers/gravity flap units as required.
- The exhaust silencing system.

It is important that the generator set itself is isolated from the enclosure components, to minimise vibration transmission. This is achieved using anti-vibration mounts under the set itself, a flexible connector between the radiator and discharge attenuator, and a flexible bellow in the exhaust system (plus flexible links in fuel lines etc.).

Fig. F12 shows a fairly typical layout. Although this shows the enclosure/set sitting on a concrete plinth, in many situations 'packaged' units are supplied - for example when the unit sits on I section steel joists or on raised concrete piers. For these applications the enclosure has a separate steel base, or the set is supplied in a 'containerised' unit.

Noise Levels

For arrangements such as this noise levels of 70-85 dBA at 1m are readily achievable for most sets. Lower levels down to 60/65 dBA at 1m can be achieved but require special attention to the ventilation attenuation and exhaust systems. With regard to the latter, noise radiating from the casings of external silencers can be problematical for lower noise levels, requiring them to be located inside the enclosure, and thermally lagged to control radiated heat.

It should also be noted that - at lower noise levels - air flow noise at weather louvres can cause high frequency problems.

Very Low Noise

Fig. F13 shows one arrangement for an enclosure to meet lower noise specs. This arrangement can also be used where 'cleaner lines' are required for aesthetic reasons - the conventional '3 box' arrangement of an enclosure with external attenuators and roof mounted exhausts is not always acceptable to architects and planners.

This particular example also shows an acoustically treated steel base - the 'package' approach previously referred to.

60 dBA at 1 m generally represents the lowest practically achievable level for the 'single enclosure' approach. If a lower level is required (and they are often asked for!) and it **is** required at 1 m, then the 'extreme' treatment of a 'double' (inner and outer) enclosure - with two stage attenuation and elaborate exhaust systems - is required. It is important to recognise that not only is the cost of such treatment very significant, but that the increased space (and weight) involved can make it impractical.

Indoor plant-room locations

Although the main principles of acoustic enclosure design and layout broadly apply to plant-room situations, the latter often have particular design difficulties brought about by building layout and space constraints.

A fairly typical situation is that of the generator(s) located below ground level in an urban office complex (Fig. F14).

If we consider ventilation aspects first, as these are often problematical in their own right (without the complication of noise control), particularly on multiple set installations.

Ventilation

Ventilation paths can be somewhat restricted (due to limited shaft areas available to/from ground level), and an added complication is that frequently only one outside wall/well is available. This can cause problems in terms of getting an acceptable airflow pattern across the set (i.e. avoiding 'dead' spots at the alternator end) and - more particularly - in terms of possible recirculation of hot air between the air discharge and air inlet. This leads to overheating (and eventual shutdown) of the generator set, and needs controlling using barriers in/around ventilation spaces.

These problems are exacerbated with the introduction of noise control. Such ventilation paths invariably terminate at street level, where relatively severe noise constraints will apply (55-60 dBA at pavement level is a typical requirement).

Attenuators

To achieve the high degree of attenuation required along what is unlikely to be a 'straight through' type ventilation path often means that conventional 'cased' attenuator units cannot be used. One proven approach is to construct acoustic plenum chambers from acoustic panels, creating the attenuators therein using acoustic splitter elements (Fig. F15).

Noise via the ventilation system is often the most difficult problem to solve, but it is by no means the only consideration. Noise breakout to adjacent areas via the plant-room walls/ceiling slab can also be a problem. Whilst the attenuation achieved through standard wall/slab constructions is normally appreciable, it must be remembered that internal noise levels for (say) office areas are considerably lower than might be required at the external louvres.

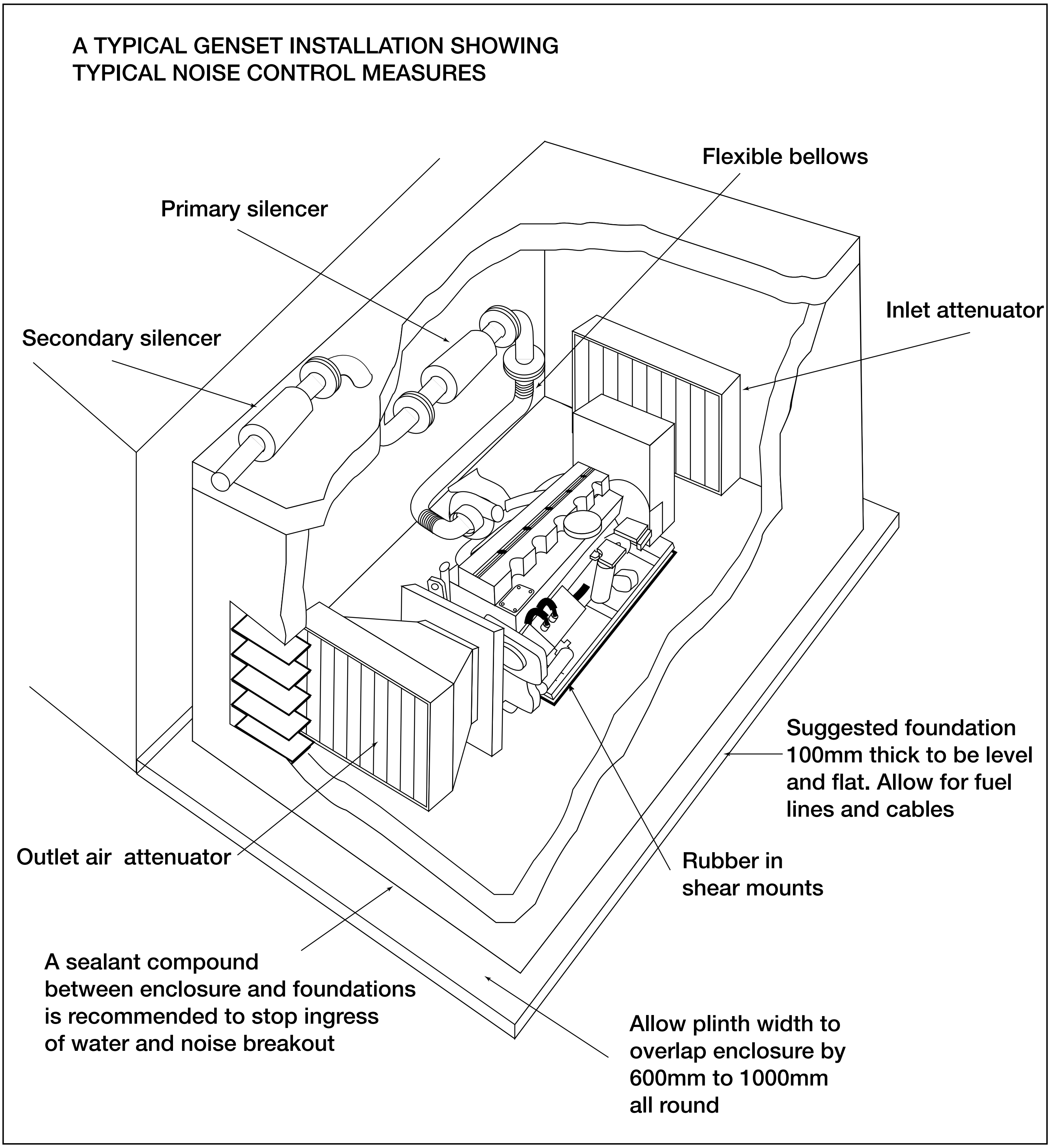

A TYPICAL GENSET INSTALLATION SHOWING
TYPICAL NOISE CONTROL MEASURES
Flexible bellows
Primary silencer
Inlet attenuator
Secondary silencer
Suggested foundation
100mm thick to be level
and flat. Allow for fuel
lines and cables
Outlet air attenuator
Rubber in
shear mounts
A sealant compound
between enclosure and foundations
is recommended to stop ingress
of water and noise breakout
Allow plinth width to
overlap enclosure by
600mm to 1000mm
all round

Fig. F12

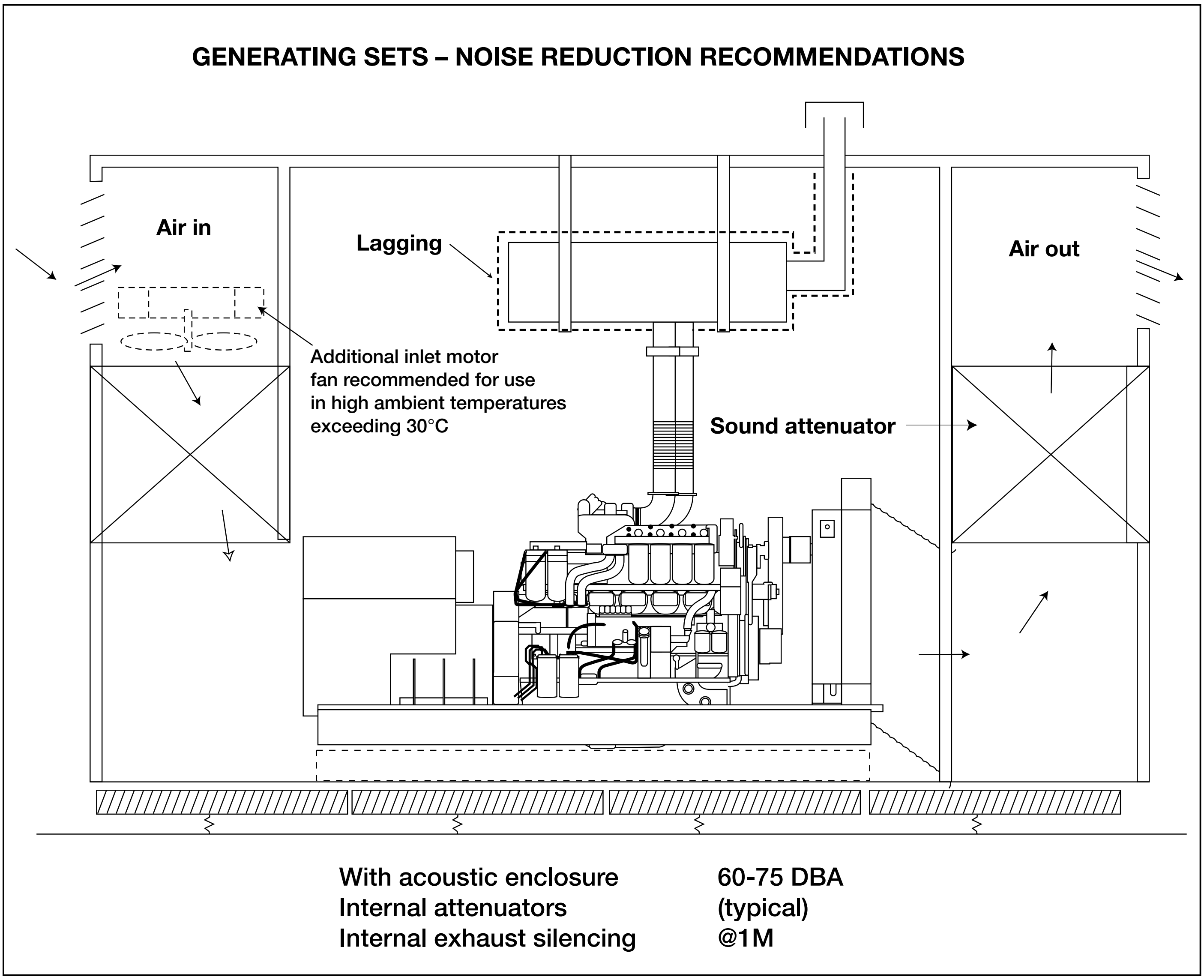


Fig. F13 Arrangement to meet low noise specifications.

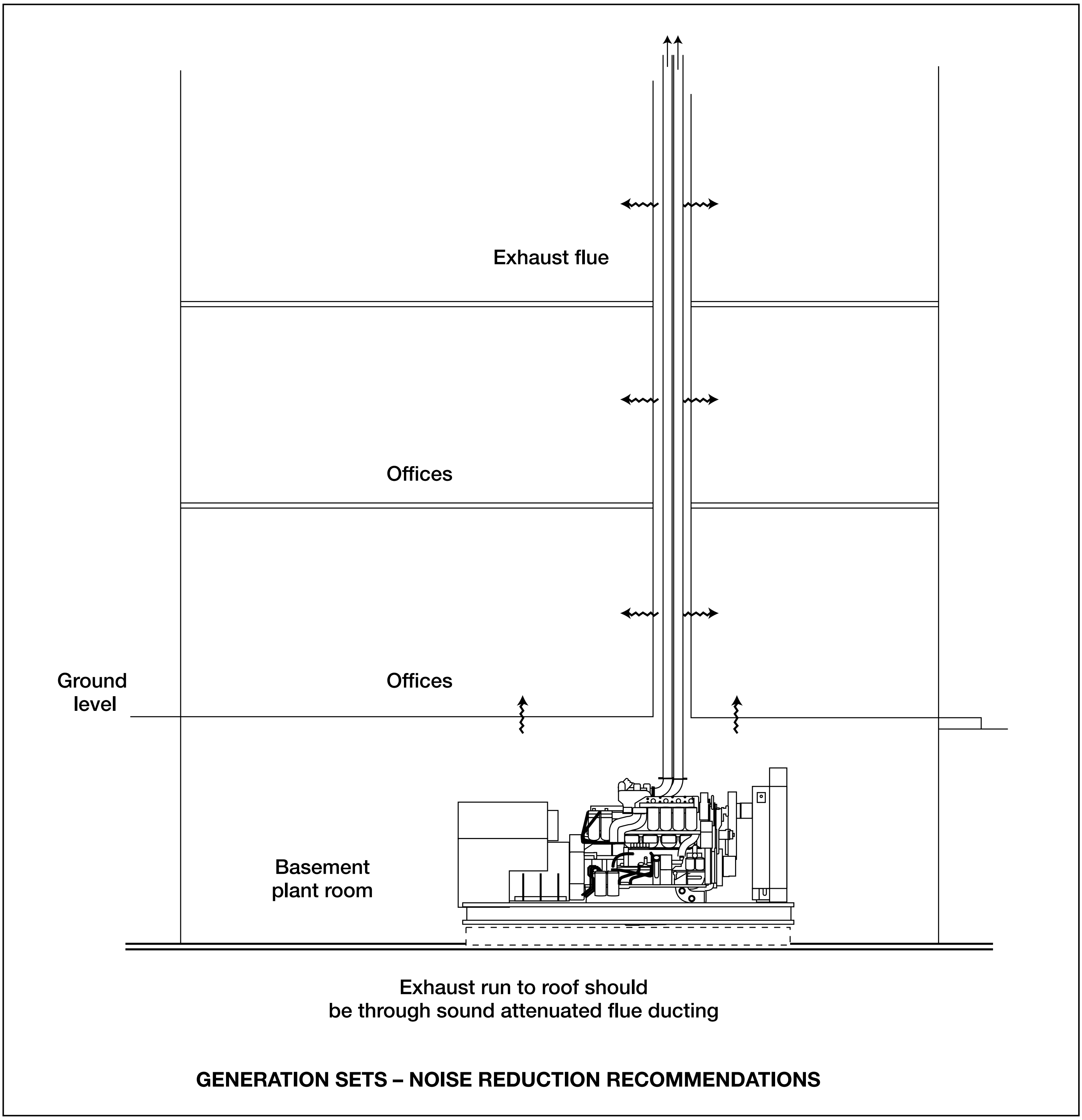


Fig. F14 Generator located below ground level.

Sound attenuators inside a plant room for two 1256kVA CP1250-5 sets

1000kVA Super Silenced (75dBA@1m) automatic standby set for major hypermarket chain warehouse

GENERATING SETS – NOISE REDUCTION RECOMMENDATIONS

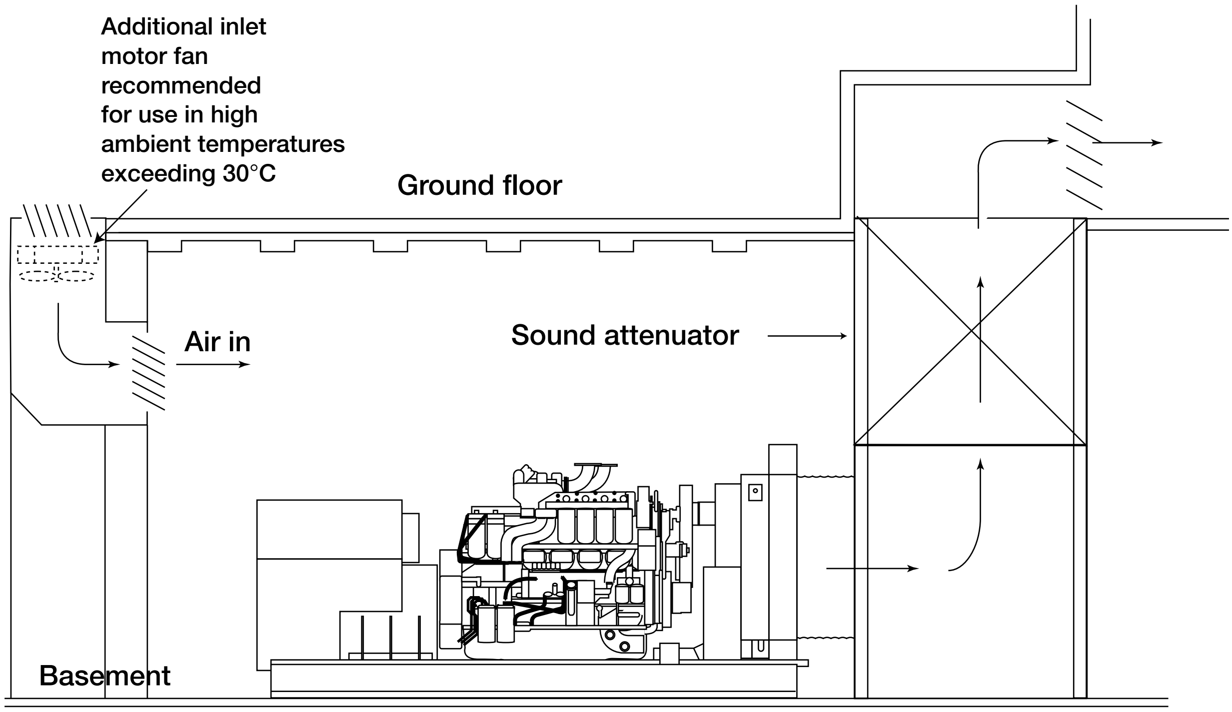


Fig. F15 Acoustic plenum chamber silencing.

Plant-room locations (cont.)

Thus with a plant-room noise level of (say) 105 dBA, and typical reductions through walls of 25-35 dBA, and through a ceiling slab of 30-40 dBA, resultant levels in adjacent areas would be 70-80 dBA (the other side of the walls) and 65-75 dBA (above the slab). Whilst areas to either side of the generator room may well be non-critical (e.g. if they are other plant-rooms), areas above are usually office/reception areas, where maximum tolerable levels are likely to be 45-55 dBA.

Room Treatment

To significantly improve noise breakout levels - either involves fitting an indoor style acoustic enclosure around the set (space/access problems often preclude this) or adding acoustic panel wall/ceilings to the room. It is important to recognise that such treatments are different to simple absorptive lining treatments. These latter, which are applied direct onto the surfaces involved, simply introduce areas of adsorption into the area, reducing the reverberant noise level in the plant-room.

Whilst this reduction (typically about 5 dBA) in **internal** plant-room noise level will also manifest itself as a reduction in noise breaking through to adjacent areas, such treatments do not significantly improve the sound insulation of the wall/slab treated.

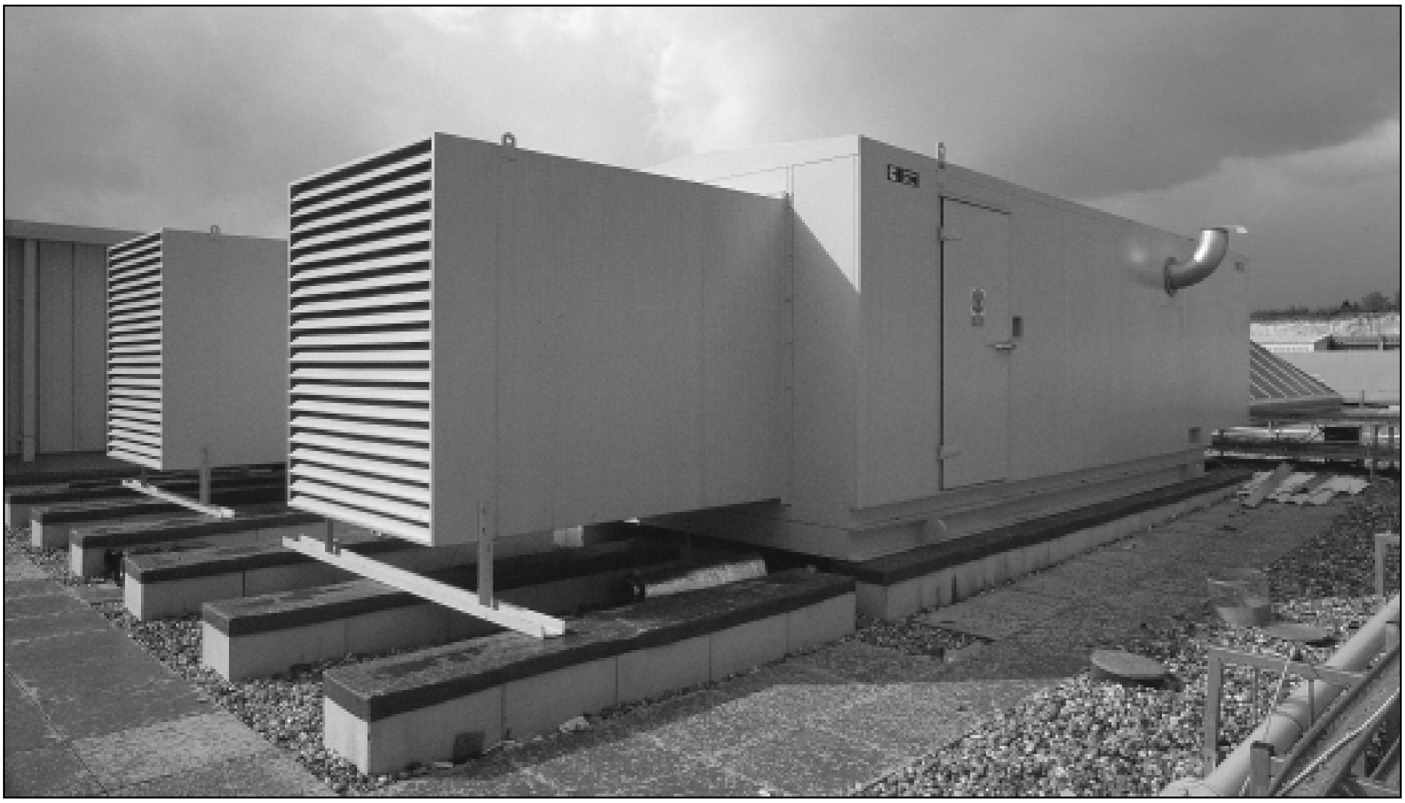
By using secondary acoustic panel treatments **spaced off the wall/slab concerned** the noise breakout level can be reduced by 10-15 dBA. On acoustic ceilings it is important to minimise rigid fixings to the slab, using spring hangers where possible.

Plant-Room Doors

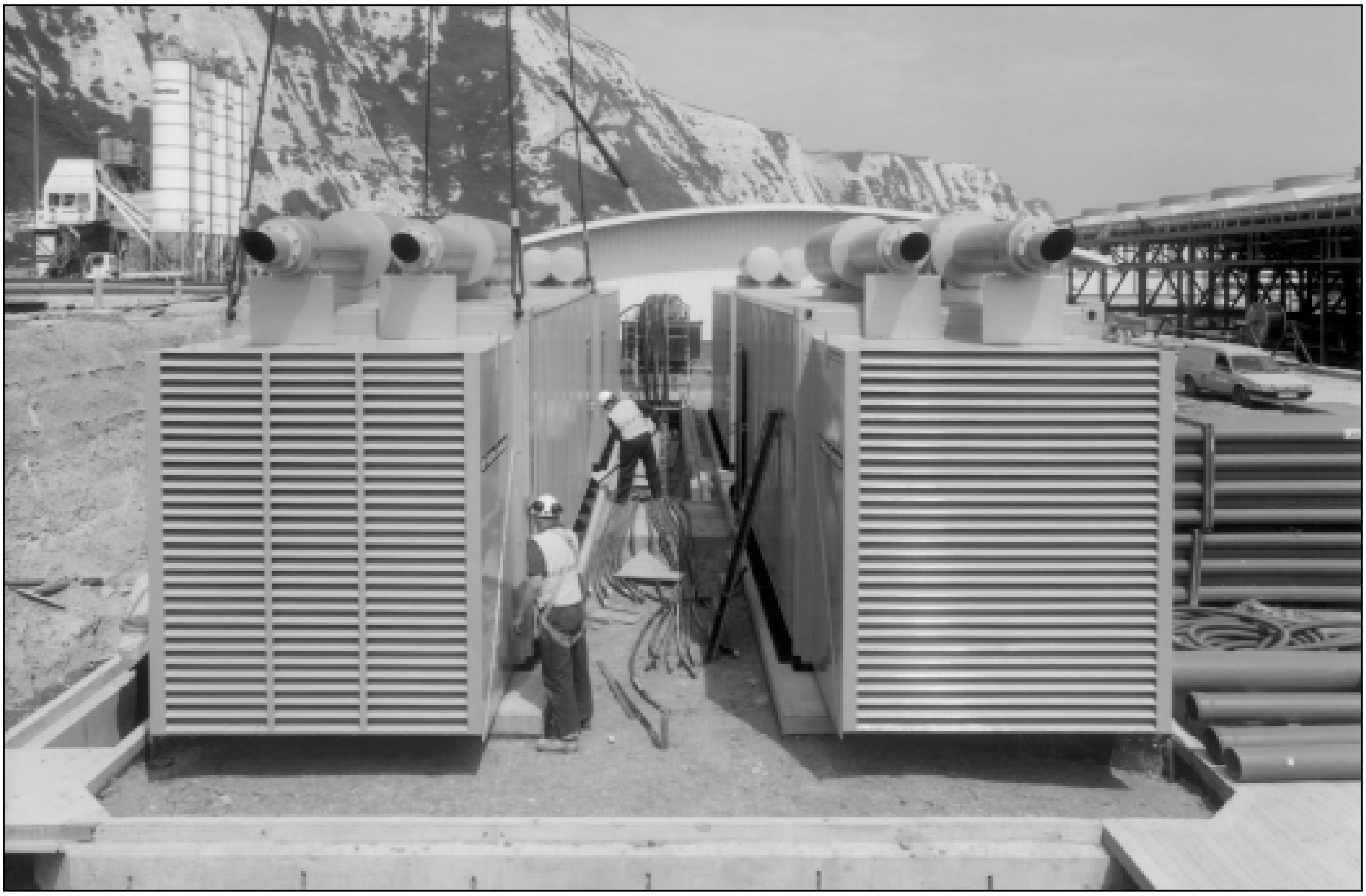
One final (but critical) point concerning noise breakout from the generator plant-room is that any access doors should generally be of the acoustic type (of appropriate performance), and consideration must be given to noise breakout via pipe/cable penetrations - particularly trenches which often pass under dividing wall lines.

Exhaust system

Turning now to the exhaust system - this is often overlooked somewhat on the basis this is frequently piped via a flue to roof level, and so assumed that ‘residential’ grade silencing is adequate. Whilst this may be acceptable in many cases, consideration should be given to noise from the flue itself (Fig. F14). Even with primary silencing carried out in the generator room, residual noise levels inside the exhaust riser are still relatively high (possibly 90-100 dBA), and if the riser shaft is constructed from lighter weight materials, or has access doors/panels then noise breakout to low noise level offices can be a problem. In terms of noise at the exhaust termination, this should obviously relate to spec. levels at (say) surrounding buildings - or noise breaking back into the building served. For particularly low levels regenerated noise caused by the relatively high pipe velocities can be a problem.



Two 1000kVA silenced standby sets with 'drop over' enclosures at roof top level eliminate many problems but create others



Four 1250kVA automatic starting, auto sync sets in specially adapted containers reduce noise levels down to 75dB(A)@1m Photo: Courtesy of EuroTunnel - Transmanche link

12m (40ft) silenced container enclosures a 2000kVA standby generator. Low noise level allows close proximity to building for short cable runs.

Modular construction cuts time factor down significantly on site.

Complete installation with roof mounted radiators and exhaust system for 1750 kW gas powered set.

Large containerised generators for isolated locations provide a convenient package for transportation and fast installation.

Roof top locations

Not all generators are located in basements, however, and mention should be made of units in higher level - or rooftop - plant-rooms . The main additional problem here is noise breakout through the floor slab to areas below (which are generally noise sensitive). This can be controlled by full floating floors, although these are often problematical with large heavy items such as generator sets.

A more practical approach is to have the generator set on plinths (using suitable high performance anti-vibration mountings) with an 'infill' acoustic floor for the intermediate spaces.

Table 8 summarises plant-room treatments for a range of external noise levels.

Table 8

DIESEL GENERATOR INSTALLATIONS - PLANT ROOM.
ELEMENTS RELATIVE TO NOISE LEVELS (GUIDANCE ONLY)

Noise Level	Louvres/Attenuators	Doors	Walls	Exhaust	Comments
85-90	Acoustic Louvres	Solid Core Timber	Blockwork	Single Residential	
75-80	Attenuators	Acoustic (Standard)	Cavity Blockwork (plastered/sealed)	Residential + Secondary or high performance	
65-70	Attenuators	Acoustic (Heavy Duty)	Cavity Blockwork (plastered/sealed)	2 residential + secondary or high performance + secondary	
55-60	Attenuators, possibly with acoustic louvres or lined bend(s). Attenuators may need panelwork casings.	Acoustic inner + outer	Cavity Blockwork + acoustic lining	4 Silencer System	Internal Enclosure - possible option. Air generated noise at louvres needs consideration
55 or less	Untypical and often impractical. Requires special consideration.				

Units of Sound Measurement

Sound power level (environmental noise) = dB(A) / 1pw

Sound pressure level (at operators ear) = dB(A)

The 'regulated' levels of sound are unlikely to be adequate for standby generators located near to sensitive environments such as hospitals, offices, public places and residential districts.

Measurement of Sound - Decibels

Pressure Measurement

Each crest of a sound wave arriving at the ear causes the eardrum to flex inward. A powerful wave with high crests will cause more eardrum flexure than a weaker wave and so the brain perceives one sound as being more loud than another.

The diaphragm of a microphone behaves exactly the same way as the eardrum when struck by a sound wave. A microphone, augmented by amplifiers, rectifiers and a measuring instrument can thus measure the sound pressures of different sound waves and therefore determine the intensity of the sound.

Logarithmic Decibel Scale

Absolute values of sound pressure and sound intensity can only be expressed in long and cumbersome numbers. The use of a logarithmic scale makes it much easier to express the levels in convenient terms. The unit of measurement on this scale is called the 'bel' after Alexander Graham Bell. In practice, for the sake of being able to work with whole numbers, it is customary to multiply values in bels by 10 and to express the values in decibels (dB).

The decibel rating of a given sound indicates the level of sound pressure or intensity at which it lies. The threshold of hearing (Fig. F16) at a frequency of 1000 Hz gives the starting point of 0 dB, and the threshold of pain is reached somewhere between 120 and 130 dB.

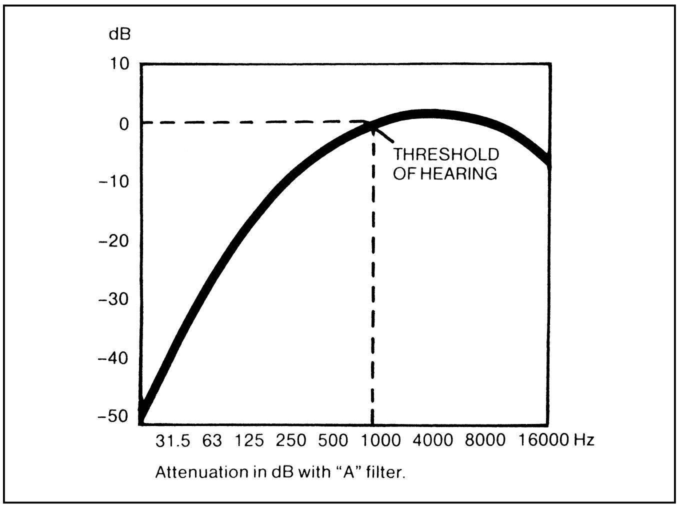


Fig. F16 Attenuation in dB with 'A' Filter

But we have to be careful with decibels, logarithmic numbers cannot be added together in the same way as ordinary numbers. Thus a rise of 3 dB corresponds to a doubling of sound intensity, while a rise of 10 dB from a given level means that the sound intensity becomes 10 times higher than before.

Frequency Filter

Although two sound waves with different frequencies may have the same sound pressure, we do not necessarily hear them as loud. This is because the ear is most sensitive in the 2000 to 4000 (2 - 4 kHz) range, while lower frequencies in particular are not picked up as well. Allowances are made for this non-uniform sensitivity when noise levels are measured. Most sound level meters therefore have built in filters. They imitate the ear by attenuating the lower frequencies thereby obtaining physiologically realistic noise level readings.

There are several different types of frequency filter, but the most widely used one is the 'A' filter. This is standard equipment when measuring traffic noise, for example. Readings obtained with such meters are expressed in dB(A), the letter in brackets indicating the filter type used.

Octave Band Analysis

A measurement of true loudness requires, not only single reading of a noise-level meter, but at least eight single readings of the sound level, each reading being an indication of the noise power in part of the frequency range encompassed by the noise. Some simple arithmetical manipulation of the eight values obtained then gives the true loudness, a figure that would agree with the subjective reactions of a panel of listeners.

Most common noises consist of a mixture of separate frequencies and are not just a single frequency. A measurement of the distribution of the sound energy can be given by a sound level meter, preceded by suitable electronic circuits that separate the total frequency band into eight separate sections and allows the noise energy in each section to be separately determined. These are the eight readings known as octave band analysis.

How loud is 'too loud'

It is accepted that the 'upper threshold' of sensitivity to noises varies from person to person: variations of ±20 dB have been noted. The composition of noises in terms of frequency is another variable factor, and the effects of different parts of the noise spectrum on human physiology are well documented. The predominant frequencies in a noise are of fundamental importance when selecting the means of controlling noise.

Normal industrial acoustic-measurements systems incorporate a weighting which balances out sound in terms of human response at different frequencies. Of the three principal weighting networks (A,B and C), A equates so well with the subjective response of average people that many noise problems are assessed in terms of the A-weighted decibel, denoted dB(A).

Specifying sound - Decibels and noise ratings

Decibels

Sound levels in decibels should be defined by one of the three principal frequency filters, namely A, B or C. For example, most sound levels, if intended to relate directly to human hearing should be defined in dB(A) terms.

But dB(A) figures by themselves are valueless until applied to a distance, for example 83 dB(A) at 1 metre.

This is essentially the 'average' value of decibel readings at specific frequencies taken across an octave of eight frequency bands, say from 63 to 8000 Hz.

Noise Rating (NR terms)

A further and lesser used system to define the noise level for a generating set is the NR (Noise Rating) method as illustrated in Figure F17.

In this case the specification could call for an NR40 rating at 30 metres for example. The NR ratings are an arbitrary scale and are used as a guide to the 'annoyance' factor that a certain level of noise will create in the minds of those exposed to the irritation.

Scales for dB(A) levels and the eight frequency levels (as in Fig. F16) are the accepted international standards for noise measurement. The NR ratings on the RH side of the diagram, however, are 'values of annoyance'. The accompanying table gives an indication of possible results using this method.

Sound of equal loudness but of different frequency do not produce equal degrees of irritation, high frequency noises being much more 'annoying per decibel' than an equal lower frequency noise. Instruments do not take this into account but as Figure F17 shows, graphical illustration does.

Each curve is a contour of 'equal annoyance', indicating the sound intensity required at each frequency to produce the value of annoyance mark at the right hand side of the curve.

To test, readings of sound intensity, in each of the eight octave bands, can be taken by a sound level meter preceded by an octave filter and plotted on the curve sheet. The points should then be joined together by straight lines. The resultant plot gives this noise a 'Noise Rating', the rating being taken at that point of the curve immediately above the highest plotted rating.

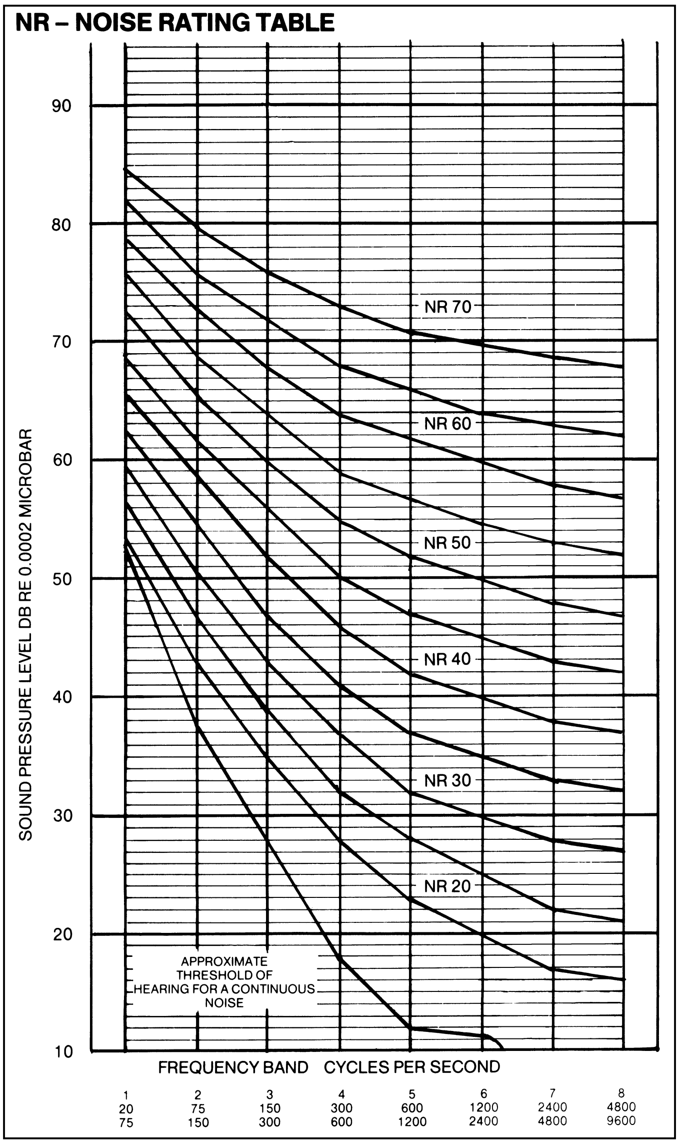


Fig. F17

For anyone to specify noise levels below - say NR40 - it is necessary for them to specify the distance away from the generating set that the readings are taken. For instance, a generator 30 m away will probably comply, but not 15m away. As an approximate guide to "noise annoyance" levels, the following NR ratings are indicated and apply to Figure F17.

- NR40 and below - No observed reaction
- NR40 to NR50 - Few complaints
- NR45 to NR55 - Main sector for complaints
- NR50 to NR60 - Legal action possibly threatened
- NR65 and above - Action taken

By comparison with actual environments (Figure F19) illustrates NR ratings against specific locations.

Fig. F18

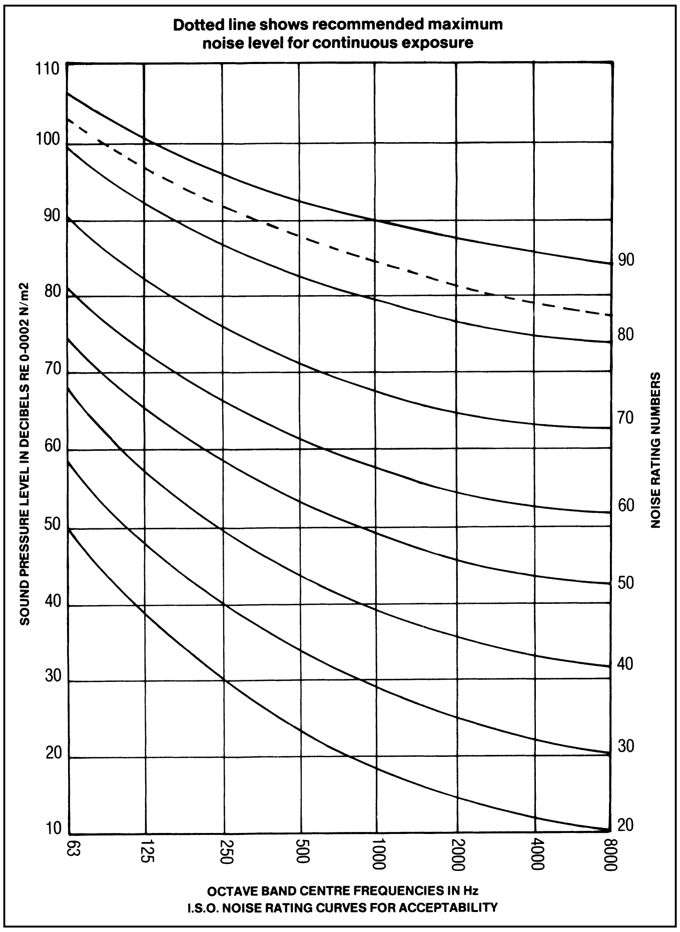


Fig. F19 NR - Noise Rating Table

Noise Rating Number	Type of Room
15	Broadcasting Studio
20	Concert Hall or Theatre
25	Bedroom, large conference room, classroom, TV studio
30	Living room, small conference room, hospital, church library
40-50	Private office, gymnasium, restaurants
50-55	General office
65-75	Workshops

Table. F20 Decibel Rating - (dB) - Environments

Decibels	**dB**
Threshold of hearing at 1kHz	0
Studio for sound pictures	20
Residence - no children	40
Conversation	60
Heavy Traffic	80
Underground train	100
Close to pneumatic drill	120
Gas turbine engine at 30m (damage to ears)	140
Rocket engine at 30m (panting of stomach)	160
110dB in vicinity of airports	
Logarithmic scale of measurement	
Sound of 1 watt at 0.3m distance	= Intensity of 10^4 (painful to ears)
Each step of 10 decibels	= Increase of intensity of 10 times
Therefore 20 dB	= 100 times the minimum
Therefore 30 dB	= 1000 times the minimum

Acoustically Treated Enclosures for Cummins Generating Sets

Attenuation

The standard enclosures are designed to give a noise reduction of 15 to 30 dB(A) and relate to the two standards of silencing produced by Cummins Power Generation ie: (see Fig. F21)

Silenced sets - 85dB(A)@1m

Supersilenced sets - 75dB(A)@1m

General Specification - Package Units

In noise critical installations, the addition of acoustic enclosure over the generating set will normally reduce the mechanical noise to an acceptable level.

The enclosures are pre assembled on a channel support. The exhaust silencer(s) will be mounted within the enclosure. The primary silencer is normally lagged with insulation to reduce the radiated heat. The exhaust is discharged to atmosphere through a tuned tail pipe in the direction of the cooling air flow. A flexible exhaust section is incorporated between the engine outlet and the silencer to isolate the enclosure from vibration. The generating plant is fully protected against the weather by the enclosure. Hand pumps are recommended on the plant for filling the fuel tank and draining the engine lubricating oil and, on large plant, for filling the radiator water cooling system. Doors are provided in the enclosure to gain access to the plant for routine maintenance and operating controls, but for major overhauls, the enclosure may be lifted clear.

Specification - Drop Over Enclosures

Require a concrete pad for generator and enclosure. Generator is positioned and silenced enclosure ‘dropped over’, leaving only the exhaust system to be connected and cables run in to the load terminal box. Exhaust silencers are generally roof mounted.

The enclosures can also be supplied for assembling over a generating plant inside an engine room to isolate the rest of the building from noise. With this type of installation, additional exhaust piping and cooling air ducting may be required. The enclosures can be used equally well for mobile generating plant, and in these cases the trailer should be suitably uprated to allow for the additional weight involved.

Examples of Noise Level	dB
Very noisy factory, Thunder	110
Unsilenced pneumatic drill	100
Underground train	90
Construction site, Busy street	80
Normal office, Restaurant	70
Conversation @ 1m	60
Quiet office	50
Quiet park	40
Residential suburban night	30
Quiet garden at night	20
Quiet church	10
	0

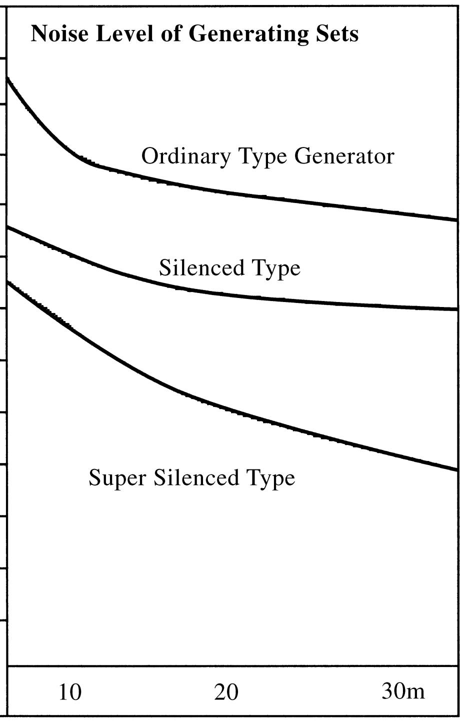


Fig. F21

Sound Reduction - Site Conditions

As noise is highly modified by its surroundings, it is essential to know the ultimate location of the generating plant. This usually falls into separate categories: Installed in a plant room or external to a building in the open. The following questions need to be answered:

1) What is the existing noise and vibration climate of the site?
2) What is the maximum noise level allowable in the surrounding area?
3) Is the predetermined noise level realistic?
4) If an existing plant room, what is the insulating and isolating performance of the building?
5) Is there sufficient ventilation for the plant?
6) What is the permissible floor loading of the site?

Existing Noise on Site (See Table 2 page F10)

It is always advisable to measure the existing background noise level before installation of the equipment, as it is pointless to attempt to attempt to reduce the noise levels below those already existing. There are, however, exceptions to this in certain parts of the country, where there is an obvious attempt by local authorities to reduce the overall noise pollution. Although many existing sites are extremely noisy during working hours, they may be extremely quite at night-time and this should be borne in mind, particularly if the standby plant may be required to run outside normal hours.

Realistic pre-determined Noise Levels

As previously pointed out, there is little point in attenuating noise to ridiculously low levels. In certain cases (TV and radio studios, hospitals etc.), very low noise levels are required but these are generally well specified.

In the main, noise levels of 60 dBA are usually acceptable for residential areas and to attempt to reduce the noise levels below this figure is costly and can add considerably to the size of an installation (a 40 dBA outlet attenuator can exceed 2m in length)

Insulating and Isolating Properties of Plant room materials.

We should first consider the terms used:

Sound Insulation

This is the reduction in sound energy achieved by a structure separating a noise source from a quiet area. Sound insulation term is only used when a reduction of airborne sound is involved and implies a net reduction in sound when it is transmitted by walls etc. connecting two rooms.

Sound Isolation

A term used for the transmission originating at impacting or vibrating sources, i.e. water hammer in pipework, slammed doors, vibrational excitation originating at machinery. The ability of a partition to resist impact noise is dependant on the character of the surface receiving the energy. The effectiveness of a partition to act as an insulator is determined by the following parameters:

1) Weight
2) Stiffness
3) Homogeneity and uniformity
4) Discontinuity and isolation

The following list gives some idea of the average Sound Reduction index for typical building materials.

Doors	
Hollow door with 3mm wood panels	15dB
42mm solid wood, normally hung	20dB
Glass	
3mm	26dB
6mm	30dB
12mm	33dB
Double glazed units with two 6mm panels and 12mm gap	40dB
Plaster	
50mm	35dB
Plastered breeze block	40dB

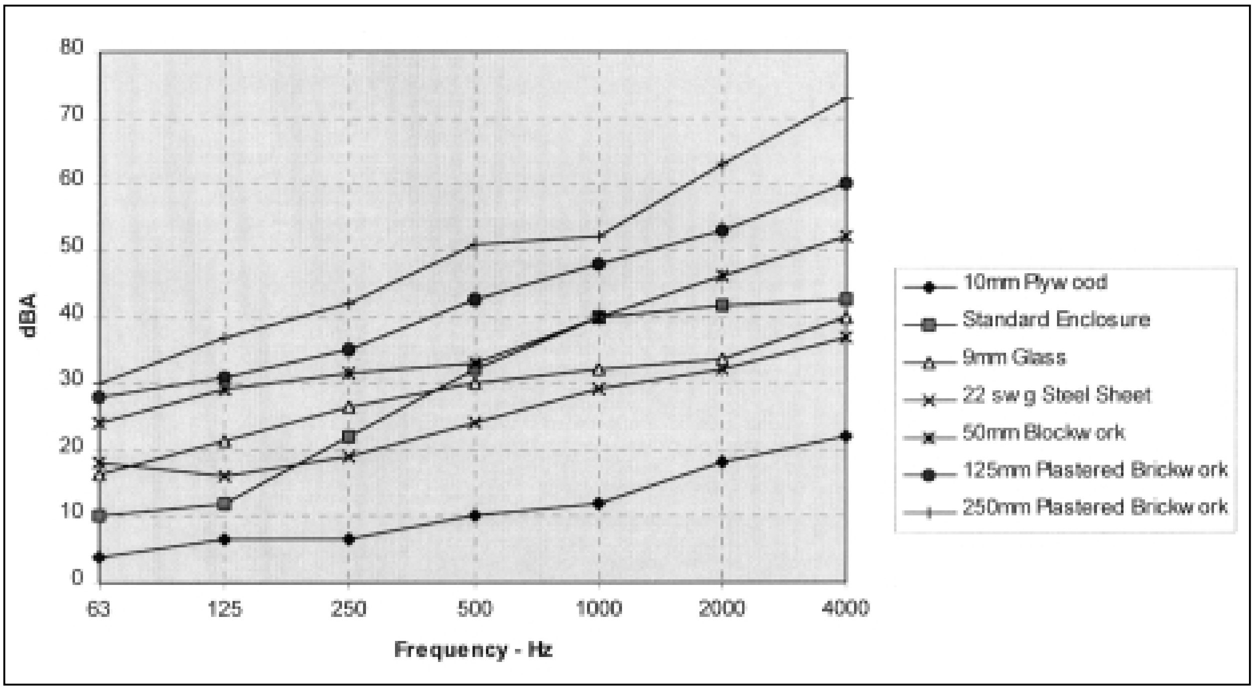


Fig. F22

Brickwork

100mm unfinished breeze block	20dB
110mm brick	45dB
220mm brick	45dB
350mm brick	50dB
450mm brick	55dB

A guide to the Sound Reduction Index can be arrived at by the following formula:

$R_{mean} = 20 + 14.5 \log_{10} W$ dB

Where W is the superficial weight in lb/ft^2

Plant Ventilation

An important factor in specifying noise control equipment for diesel generating plant is the need for adequate provision of air into and out of the plant room or enclosure. As the larger plant (800kW) require a combustion air volume of around 3200 c.f.m. and a radiator throughput of 40 000 c.f.m., this can entail using quite large attenuators if the pressure drop is to be kept to reasonable figures.

Certain locations may require the air to be ducted in from the outside and allow for this in the site survey.

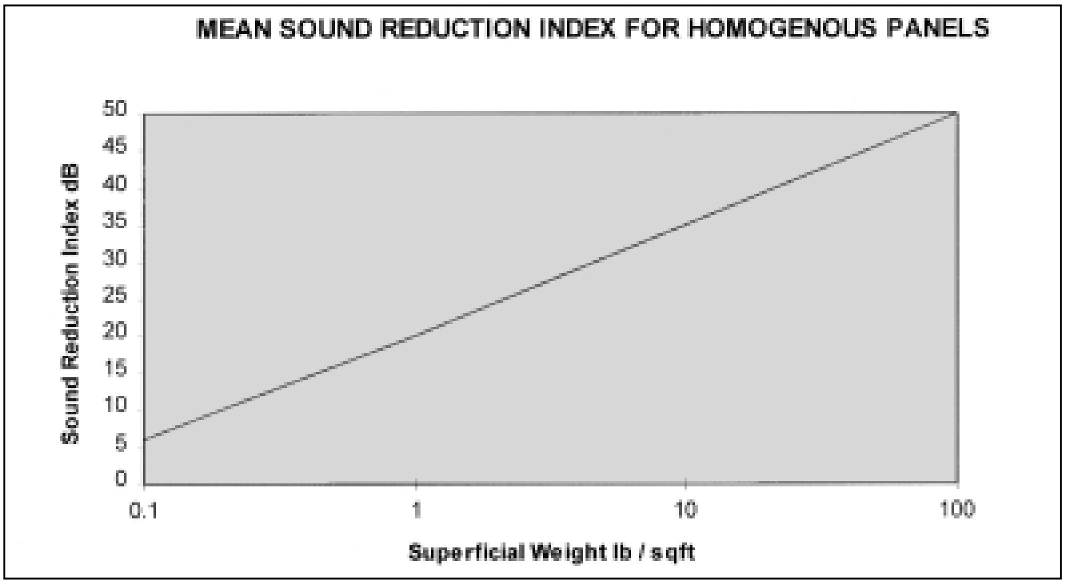


Fig. F23

6. Floor Loading

The acoustic mass law relates the superficial weight of a partition to its transmission loss. In general, for every doubling of the weight , there is an increase in insulation of about 5dB.

As most acoustic partitions have a weight of approximately 41kg/sq.m.(10 lb/ft^2,) it can be seen that the overall weight of an enclosure can be quite large, i.e. an 2.4m (8 ft) wide by 4.6m (15 ft) long enclosure for a 300 kW generator can weigh 4 tons. If you add to this the weight of the plant it is easy to see that there will be a considerable floor loading at the site.

There are many factors which can modify the sound level on site - either increasing or decreasing the sound pressure level. Amongst these factors are :

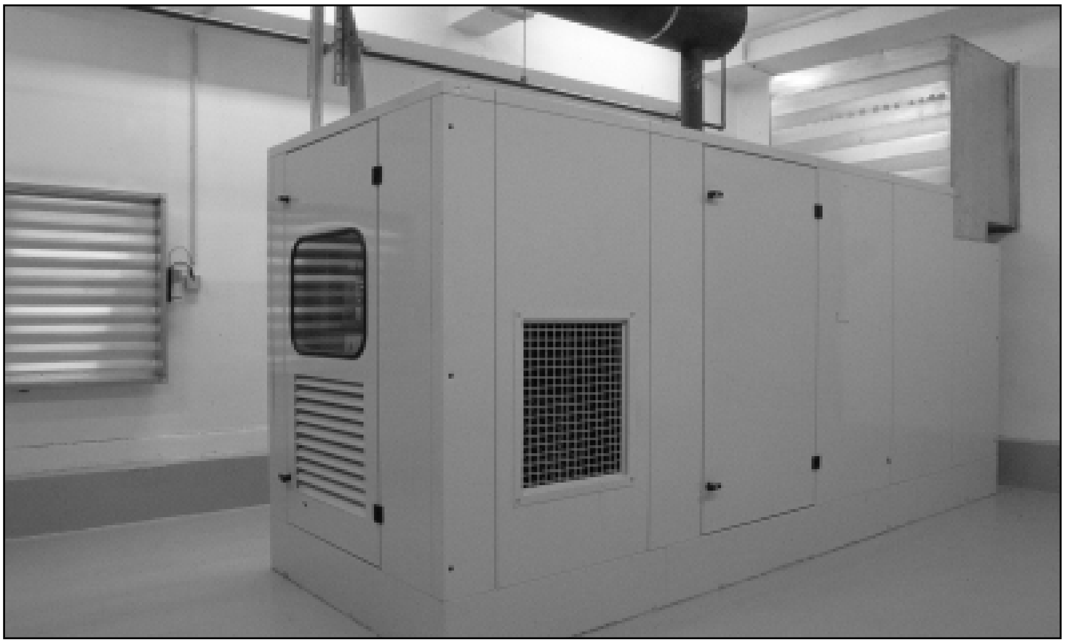
Absorption of sound energy in the atmosphere.

Diffraction due to atmospheric gradients of temperature and wind speed.

Reflections from buildings.

The directivity of the noise.

The addition of one or more sets in a generator room.



Cummins 1100kVA Supersilenced generating set installed inside an acoustically clad plant room. Method will achieve an ultra quiet solution for noise sensitive locations such as this Hilton Hotel.

Cummins Power Generation

Installation of a Closed Set

For the most effective reduction in noise levels, it is recommended that the installation be isolated and as far away from working, office and residential quarters as possible. This may prove impractical on occasions and does mean increased costs for cable and fuel pipe runs.

Control cubicles can be located inside the enclosure mounted on the set and for manual electric start versions, this is recommended. For automatic mains failure system, the changeover contactors or ATS units should be located as near to the incoming mains as possible to avoid unnecessary cable runs. Protected gullies in the plinth are necessary for the output cables.

Sets can be provided with integral fuel tanks or from an externally mounted day tank with an automatic fuel transfer system from the bulk tank, which is recommended for the permanent installation. Allowance must be made for fuel lines to run to and from the engine through the concrete plinth. Also check which side of the engine these emerge from.

Ensure that the air inlet and outlet flows are not obstructed, as any restrictions of air flows may lead to overheating, loss of output and even shutdown.

Average Sound Reduction Indices For Typical Partitions

dB				dB
10				10
	_____1mm Plywood_____			
		20 SWG Plain Aluminium		
	_____6mm Plywood_____			
20	_____9mm Plywood_____			20
	____22mm Whitewood____			
	____19mm Chipboard____	___22 SWG Sheet Steel____	___3mm Glass___________	
30	____50mm Mahogany____	___16 SWG Sheet Steel____	___6mm Glass___________	30
	____Gypsum Wallboard____	___9mm Asbestos faced___ 18 SWG Sheet Steel	___12mm Glass__________	
	__19mm Plasterboard____ Plaster Both Sides	__Corrugated Aluminium__		
40	___4 x 12mm Gypsum___ Wallboard		__50mm Reinforced concrete	40
			___125mm Plain Brick_____	
			_100mm Reinforced concrete	
50			___300mm Plain Brick_____	50
			___50mm x 200mm____ blockwork with 100mm gap in between	
60				60

Fig. F24

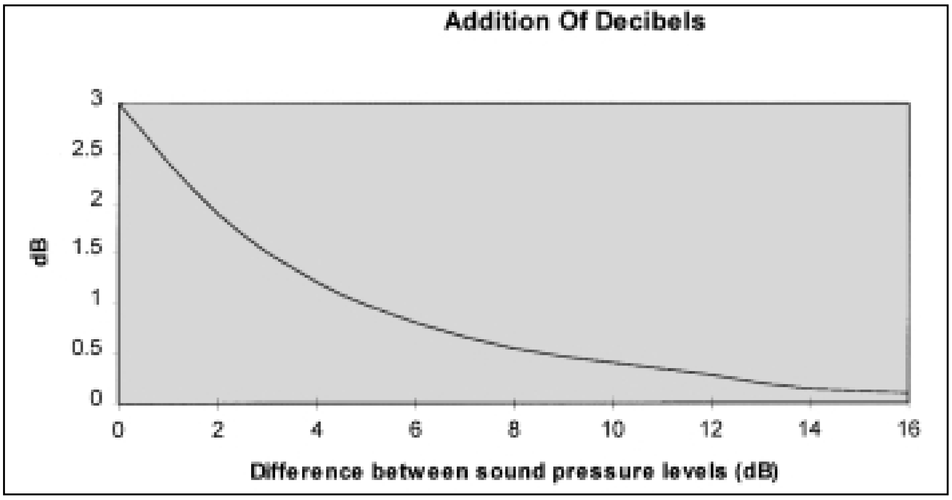


Fig. F25

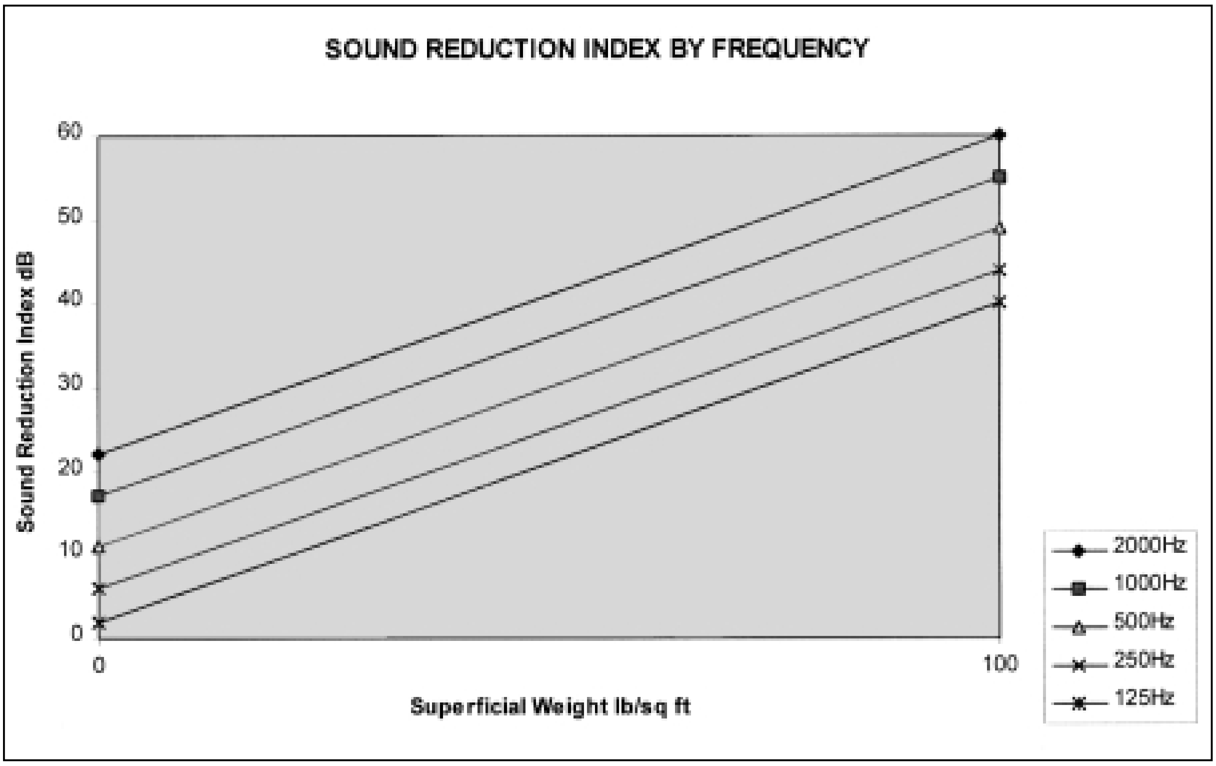


Fig. F26

ISO container (9m) 30ft unit contains 600kVA emergency generator. Silenced to 75dB(A) at 1m

Drop over supersilenced enclosure for a 3700kVA Prime Power set sits on specially prepared concrete base

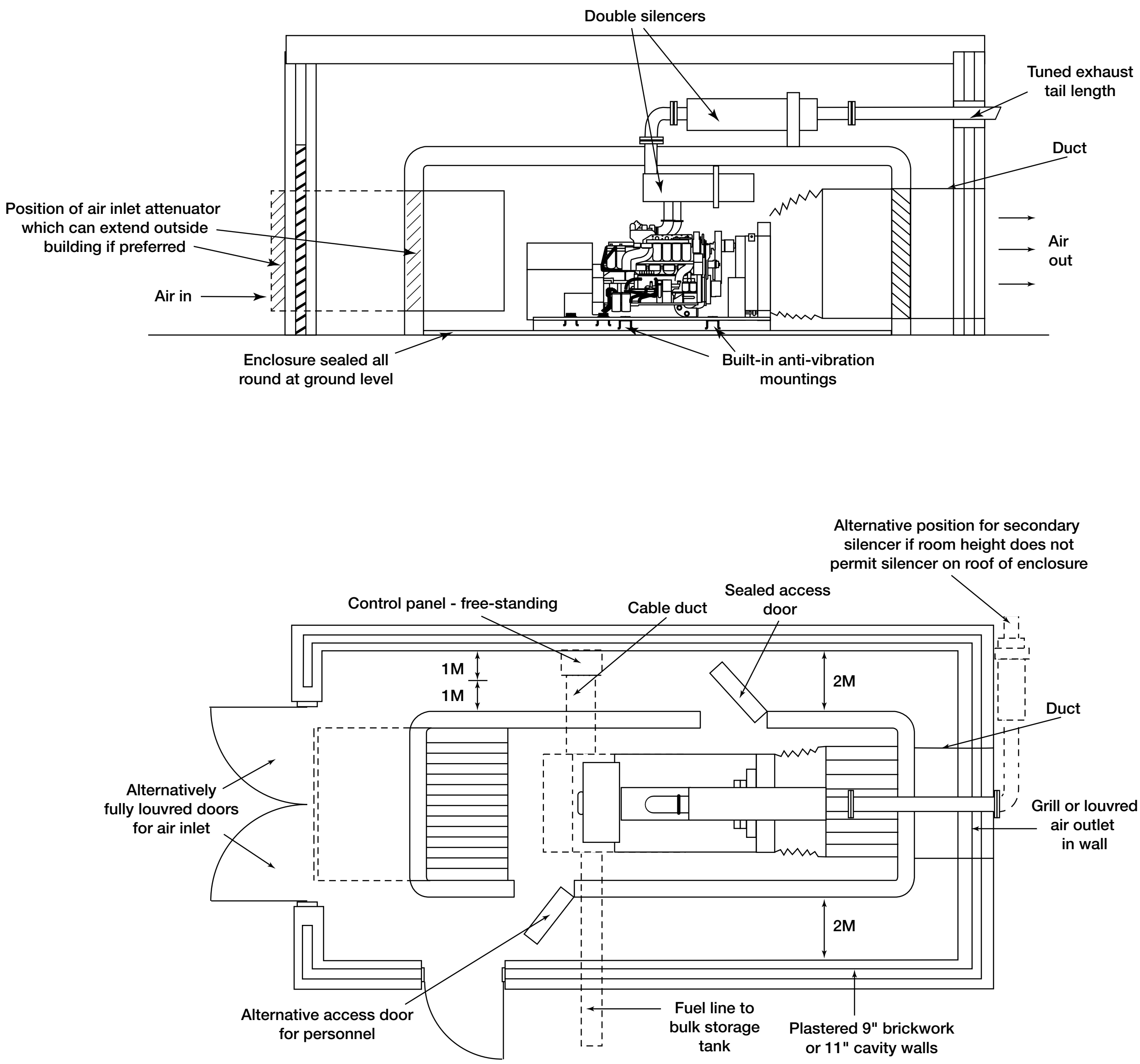
Three Cummins 1000kW silenced generators. Method of concrete foundation eliminates laying a large concrete platform over the whole area – saving costs. Method can also be used on roof top installations where point loading is sometimes necessary.

Installation of a Silenced Enclosed Set inside a Building

For extremely critical locations, where little or no noise can be tolerated, and the cost of the installation is secondary, the use of a soundproof enclosure over a generating set and all enclosed in a well built double capacity brick room is the most effective means. The soundproof enclosure is dismantled, transported into the room in sections and rebuilt in situ, as most installations of this type are in existing buildings.

Air inlet and outlet attenuators are part of the enclosure and it is only necessary to provide normal louvred apertures in the walls for air flow requirements, unless additional sound attenuators in the louvres are specifically required. This type of installation has an additional advantage - from the operator's point of view - of also being extremely quiet "within" the room as well as outside.

Height and space may prove a problem - especially if the site is a converted room in an existing building and, in these cases, the air attenuators can be positioned separately from the enclosure. The secondary silencer can be extended to an outside wall.



INSTALLATION OF A SILENCED ENCLOSED SET INSIDE A BUILDING

Fig. F27

Power Generation

50 Hz Ratings Diesel Powered Generating Sets

Prime Rating				Engine Model	Standby Rating		
KVA	KW	Prime Model	TA Luft		KVA	KW	Standby Model
32	26	26 DGGC		B3.3G1	37	30	30 DGGC
50	40	40 DGHC		B3.3G2	55	44	44 DGHC
38	30	30 DGBC		4B3.9G	41	33	33 DGBC
52	42	42 DGCG	4g	4BT3.9G4	59	47	47 DGCG
64	51	51 DGCH	4g	4BT3.9G4	70	56	56 DGCH
70	56	56 DGCC		4BTA3.9G1	78	62	62 DGCC
96	77	77 DGDH		6BT5.9G6	106	85	85 DGDH
106	85	85 DGDJ		6BT5.9G6	119	95	95 DGDJ
140	112	112 DGDE		6BTA5.9G2	154	123	123 DGDE
129	103	103 DGEA	4g	6CT8.3G2	145	116	116 DGEA
153	122	122 DGFA	4g	6CTA8.3G2	170	136	136 DGFA
185	148	148 DGFB	4g	6CTA8.3G2	204	163	163 DGFB
204	163	163 DGFC	4g	6CTAA8.3G1	NA	NA	NA
230	184	184 DGFE		6CTAA8.3G2	250	200	200 DGFE
233	186	186 DFAB		LTA10G2	259	207	207 DFAB
252	202	202 DFAC		LTA10G3	279	223	223 DFAC
NA	NA	NA		NT855G6	313	250	250 DFBF
315	252	252 DFBH		NT855G6	350	280	280 DFBH
350	280	280 DFCC		NTA855G4	390	312	312 DFCC
NA	NA	NA		NTA855G6	425	340	340 DFCE
455	364	364 DFEJ	4g	QSX15G8	500	400	400 DFEJ
500	400	400 DFEK	4g	QSX15G8	550	440	440 DFEK
431	345	345 DFEC		KTA19G3	NA	NA	NA
450	360	360 DFEL		KTA19G3	500	400	400 DFEL
511	409	409 DFED		KTA19G4	576	461	461 DFED
575	460	460 DFGA		VTA28G5	636	509	509 DFGA
640	512	512 DFGB		VTA28G5	706	565	565 DFGB
750	600	600 DFGD		VTA28G6	825	660	660 DFGD
725	580	580 DFHA	4g	QST30G1	800	640	640 DFHA
800	640	640 DFHB	4g	QST30G2	891	713	713 DFHB
939	751	751 DFHC		QST30G3	1041	833	833 DFHC
1000	800	800 DFHD		QST30G4	1110	888	888 DFHD
725	580	580 DFHE	2g	QST30G6	800	640	640 DFHE
800	640	640 DFHF	2g	QST30G7	891	713	713 DFHF
939	751	751 DFHG	2g	QST30G8	1041	833	833 DFHG
1256	1005	1005 DFLC		KTA50G3	1400	1120	1120 DFLC
1256	1005	1005 DFLG	4g	KTA50G6	NA	NA	NA
1256	1005	1005 DFLH	4g	KTA50G7	NA	NA	NA
1406	1125	1125 DFLE		KTA50G8	1675	1340	1340 DFLE
1500	1200	1200 DFLF		KTA50GS8	1675	1340	1340 DFLF
1875	1500	1500 DQKC		QSK60G3	2063	1650	1650 DQKC
2000	1600	1600 DQKD		QSK60G4	2200	1760	1760 DQKD
1875	1500	1500 DQKE	2g	QSK60G3	2063	1650	1650 DQKE
2000	1600	1600 DQKF	2g	QSK60GS3	2200	1760	1760 DQKF

Rating Conditions:

50 Hz ratings at 40°C (104°F) ambient temperature.

Ratings: Prime (Unlimited Running Time), applicable for supplying power in lieu of commercially-purchased power.

Prime power is available at a variable load for an unlimited number of hours. A 10% overload capacity is available. Nominally rated. In accordance with ISO 8528, ISO 3046, AS 2789, DIN 6271 and BS 5514.

Standby: Applicable for supplying emergency power for the duration of normal power interruption. No sustained overload capability is available for this rating. Nominally rated. In accordance with ISO 3046, AS 2789, DIN 6271 and BS 5514.

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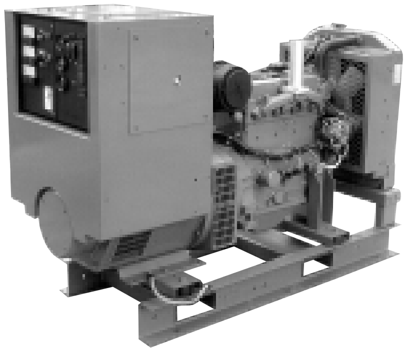
Technical Data

Power Generation

26 kW - 44 kW 50 Hz
B3 Series Engines



Generating Sets – 50 Hz

Set output	380-440 V 50 Hz	380-440 V 50 Hz
Prime at 40°C ambient	26 kWe 32.5 kVA	40 kWe 50 kVA
Model (Prime)	26 DGGC	40 DGHC
Standby at 40°C ambient	30 kWe 37.5 kVA	44 kWe 55 kVA
Model (Standby)	30 DGGC	44 DGHC
Engine Make	Cummins	Cummins
Model	B3.3G1	B3.3G2
Cylinders	Four	Four
Engine build	In-line	In-line
Governor/Class	Mechanical	Mechanical
Aspiration and cooling	Natural aspiration	Turbocharged
Bore and stroke	95 mm x 115 mm	95 mm x 115 mm
Compression ratio	18.2:1	17.0:1
Cubic capacity	3.26 Litres	3.26 Litres
Starting/Min °C	Unaided/–4°C	Unaided/–4°C
Battery capacity	126 A/hr	126 A/hr
Nett Engine output – Prime	31 kWm	45 kWm
Nett Engine output – Standby	34 kWm	49 kWm
Maximum load acceptance – single step	100%	100%
Speed	1500 rpm	1500 rpm
Alternator voltage regulation	±1.5%	±1.5%
Alternator insulation class	H	H
Single load step to NFPA110	100%	100%
Fuel consumption (Prime) 100% load	7.8 l/hr	11.86 l/hr
Fuel consumption (Standby) 100% load	9 l/hr	13.6 l/hr
Lubrication oil capacity	8 Litres	8 Litres
Base fuel tank capacity – open set	150 Litres	150 Litres
Coolant capacity – radiator and engine	11.5 Litres	14 Litres
Exhaust temp – full load prime	450°C	475°C
Exhaust gas flow – full load prime	445 m^3/hr	445 m^3/hr
Exhaust gas back pressure max	76 mm Hg	76 mm Hg
Air flow – radiator @ 12mm restriction*	6582 m^3/hr	4872 m^3/hr
Air intake – engine	125.7 m^3/hr	176.7 m^3/hr
Minimum air opening to room	0.63 m^2	0.63 m^2
Minimum discharge opening	0.47 m^2	0.47 m^2
Pusher fan head (duct allowance)	12 mm Wg	12 mm Wg
Total heat radiated to ambient	10.2 kW	11.6 kW
Engine derating – altitude	0.7% per 100 m above 1000 m	0.9% per 100 m above 1000 m
Engine derating – temperature	1% per 10°C above 40°C	4.5% per 10°C above 40°C

In accordance with ISO 8528, ISO 3046.
Prime: Continuous running at variable load for unlimited periods with 10% overload available for 1 hour in any 12 hour period.
Standby: Continuous running at variable load for duration of an emergency.
Prime and standby ratings are outputs at 40°C (104°F) ambient temperature reference.
*Subject to factory verification.

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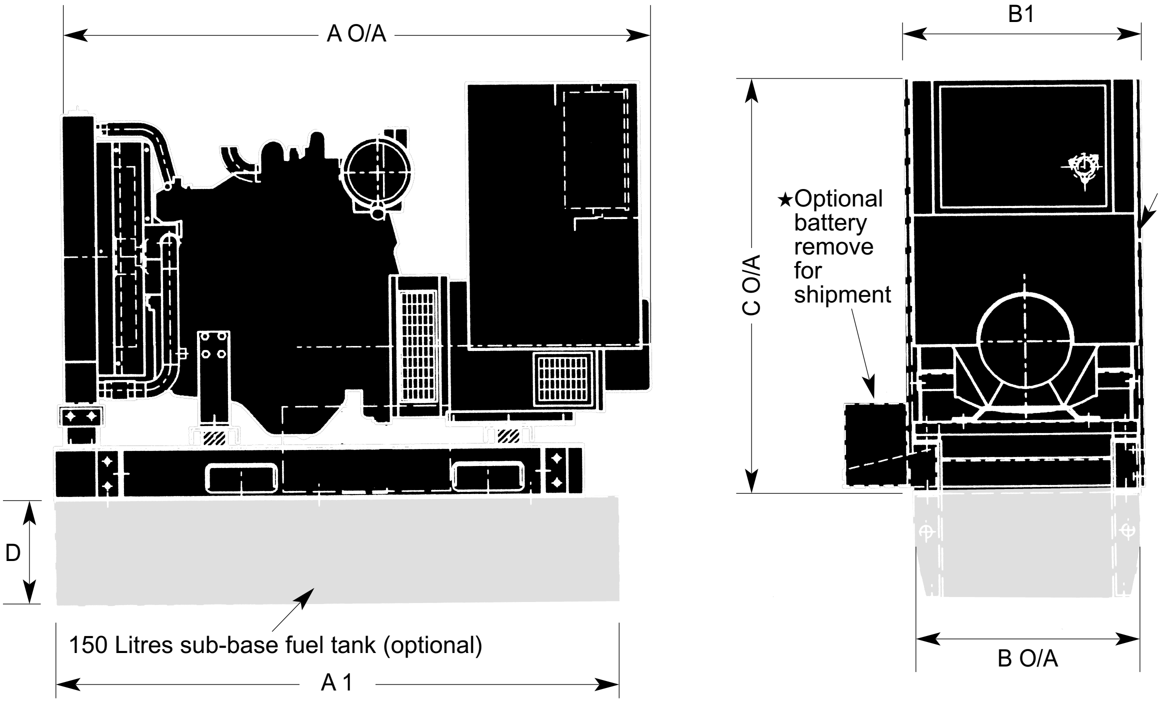
B3 Series Engines



Model	Engine	Length A mm	A1 mm	Width B mm	B1 mm	Height C mm	D mm	Set weight kg wet	Set weight kg dry	Sub base Tank. Dry Weight kg	Sub base Tank. Wet Weight kg
DGGC	B3.3G1	1667	1600	645	635	1183	300	835	819	150	299
DGHC	B3.3G2	1760	1600	645	635	1183	300	890	871	150	299

NOTE 1:
★ Dry and Wet weights of sets do NOT include fuel tank or contents.

Set weights are **without** sub-base tank. Dimensions and weights are for **guidance** only.
Sub-base tank weights are for single skin tanks.
Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

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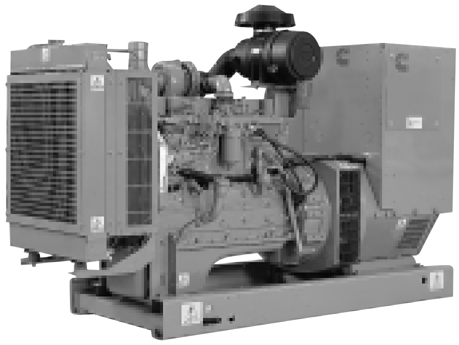
Technical Data

Power Generation

30 kW - 62 kW 50 Hz
4B Series Engines

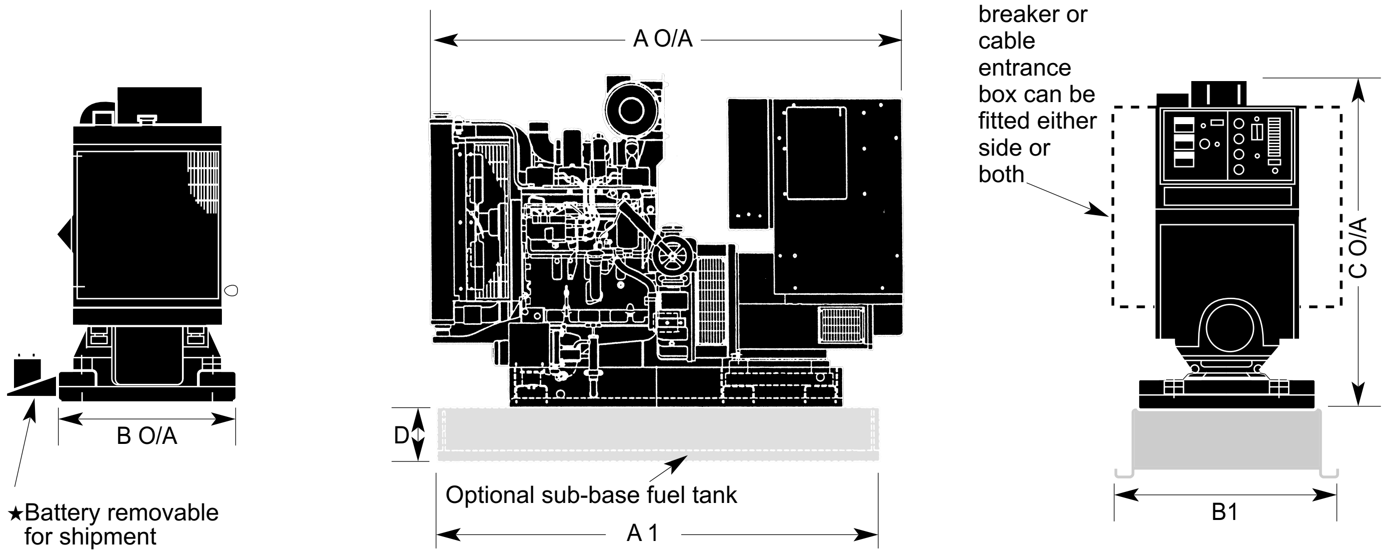


Generating Sets – 50 Hz

Set output	380-440 V 50 Hz	380-440 V 50 Hz	380-440 V 50 Hz	380-440 V 50 Hz
Prime at 40°C ambient	30 kWe 38 kVA	42 kWe 52 kVA	51 kWe 64 kVA	56 kWe 70 kVA
Model (Prime)	30 DGBC	42 DGCG	51 DGCH	56 DGCC
Standby at 40°C ambient	33 kWe 41 kVA	47 kWe 59 kVA	56 kWe 70 kVA	62 kWe 78 kVA
Model (Standby)	33 DGBC	47 DGCG	56 DGCH	62 DGCC
Engine Make	Cummins	Cummins	Cummins	Cummins
Model	4B3.9G	4BT3.9G4	4BT3.9G4	4BTA3.9G1
Cylinders	Four	Four	Four	Four
Engine build	In-line	In-line	In-line	In-line
Governor/Class	Mechanical	Mechanical	Mechanical	Mechanical
Aspiration and cooling	Natural aspiration	Turbocharged	Turbocharged	Turbocharged
Bore and stroke	102 mm x 120 mm	102 mm x 120 mm	102 mm x 120 mm	102 mm x 120 mm
Compression ratio	17.3:1	16.5:1	16.5:1	16.5:1
Cubic capacity	3.92 Litres	3.92 Litres	3.92 Litres	3.92 Litres
Starting/Min °C	Unaided/–12°C	Unaided/–12°C	Unaided/–12°C	Unaided/–12°C
Battery capacity	165 A/hr	165 A/hr	165 A/hr	165 A/hr
Nett Engine output – Prime	34 kWm	47 kWm	57 kWm	64 kWm
Nett at flywheel – Standby	38 kWm	52 kWm	62 kWm	71 kWm
Speed	1500 rpm	1500 rpm	1500 rpm	1500 rpm
Alternator voltage regulation	±1.0%	±1.0%	±1.0%	±1.0%
Alternator insulation class	H	H	H	H
Single load step to NFPA110	100%	100%	100%	100%
Fuel consumption (Prime) 100% load	9.7 l/hr	13.0 l/hr	15.0 l/hr	15.0 l/hr
Fuel consumption (Standby) 100% load	10.6 l/hr	14.0 l/hr	15.8 l/hr	17.0 l/hr
Lubrication oil capacity	9.5 Litres	9.5 Litres	9.5 Litres	9.5 Litres
Base fuel tank capacity – open set	195 Litres	197 Litres	197 Litres	195 Litres
Coolant capacity – radiator and engine	19 Litres	19.2 Litres	19.2 Litres	20 Litres
Exhaust temp – full load prime	596°C	518°C	518°C	475°C
Exhaust gas flow – full load prime	432 m^3/hr	651 m^3/hr	651 m^3/hr	598 m^3/hr
Exhaust gas back pressure max	76 mm Hg	76 mm Hg	76 mm Hg	76 mm Hg
Air flow – radiator*	2.26 m^3/s	2.26 m^3/s	2.26 m^3/s	2.27 m^3/s
Air intake – engine	144 m^3/hr	259 m^3/hr	259 m^3/hr	248 m^3/hr
Minimum air opening to room	0.7 sq m	0.7 sq m	0.7 sq m	0.7 sq m
Minimum discharge opening	0.5 sq m	0.5 sq m	0.5 sq m	0.5 sq m
Pusher fan head (duct allowance)*	10 mm Wg*	13 mm Wg*	13 mm Wg*	10 mm Wg*
Total heat radiated to ambient	10.8 kW	16.0 kW	17.6 kW	15.5 kW
Engine derating – altitude	3% per 300 m above 150 m	4% per 300 m above 600 m	4% per 300 m above 600 m	4% per 300 m above 1525 m
Engine derating – temperature	2% per 11°C above 40°C	2% per 11°C above 40°C	2% per 11°C above 40°C	2% per 11°C above 40°C

In accordance with ISO 8528, ISO 3046.
Prime: Continuous running at variable load for unlimited periods with 10% overload available for 1 hour in any 12 hour period.
Standby: Continuous running at variable load for duration of an emergency.
Prime and standby ratings are outputs at 40°C (104°F) ambient temperature reference.

4B Series Engines

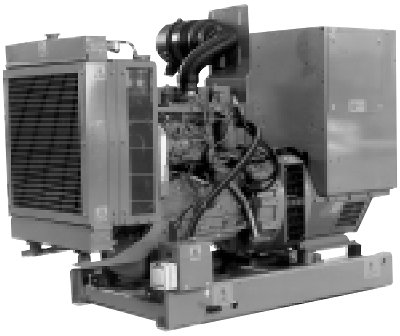


Model	Engine	Length A mm	A1 mm	Width B1 mm	B mm	Height C mm	D mm	Set weight kg wet	Set weight kg dry	Sub base Tank. Dry Weight kg	Sub base Tank. Wet Weight kg
DGBC	4B3.9G	1720	1675	840	675	1345	200	800	772	150	310
DGCG	4BT3.9G4	1810	1675	840	675	1245	200	850	822	150	310
DGCH	4BT3.9G4	1810	1675	840	675	1245	200	920	892	150	310
DGCC	4BTA3.9G1	1846	1675	840	675	1245	200	975	932	150	310

NOTE 1:
★ Battery/tray extends out 260 mm from side when fitted.
★ Dry and Wet weights of sets do NOT include fuel tank or contents.

Set weights are **without** sub-base tank. Dimensions and weights are for **guidance** only.
Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

77 kW - 95 kW 50 Hz
6B Series Engines

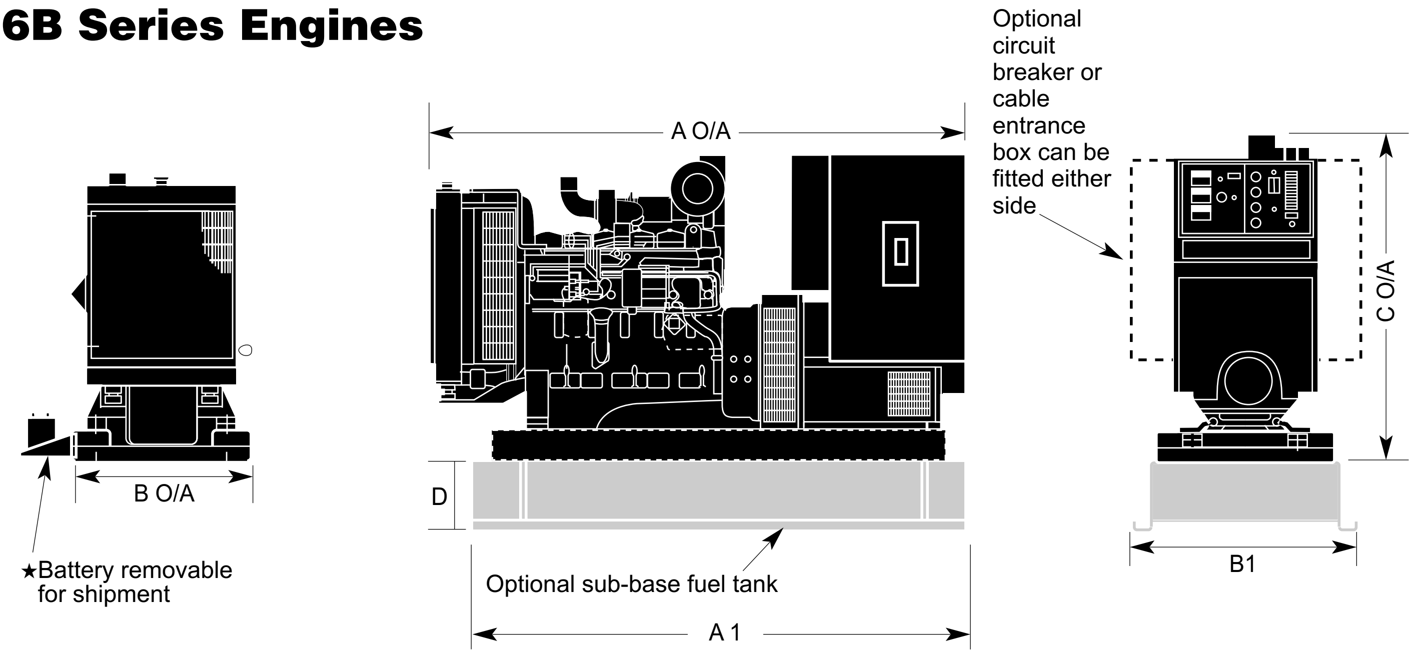


Generating Sets – 50 Hz

Set output	380-415 V 50 Hz	380-415 V 50 Hz
Prime at 40°C ambient	77 kWe 96 kVA	85 kWe 106 kVA
Model (Prime)	77 DGDH	85 DGDJ
Standby at 40°C ambient	85 kWe 106 kVA	95 kWe 119 kVA
Model (Standby)	85 DGDH	95 DGDJ
Engine Make	Cummins	Cummins
Model	6BT5.9G6	6BT5.9G6
Cylinders	Six	Six
Engine build	In-line	In-line
Governor/Class	Mechanical	Mechanical
Aspiration and cooling	Turbocharged	Turbocharged
Bore and stroke	102 mm x 120 mm	102 mm x 120 mm
Compression ratio	16.5:1	16.5:1
Cubic capacity	5.88 Litres	5.88 Litres
Starting/Min °C	Unaided/–12°C	Unaided/–12°C
Battery capacity	165 Ah	165 Ah
Nett Engine output – Prime	86 kWm	94 kWm
Nett at flywheel – Standby	94 kWm	106 kWm
Speed	1500 rpm	1500 rpm
Alternator voltage regulation	±1.0%	±1.0%
Alternator insulation class	H	H
Single load step to NFPA110	100%	100%
Fuel consumption (Prime) 100% load	21.8 l/hr	23.8 l/hr
Fuel consumption (Standby) 100% load	23.8 l/hr	27 l/hr
Lubrication oil capacity	14.2 Litres	14.2 Litres
Base fuel tank capacity – open set	200 Litres	200 Litres
Coolant capacity – radiator and engine	25.1 Litres	25.1 Litres
Exhaust temp – full load prime	552°C	552°C
Exhaust gas flow – full load prime	1026 m^3/hr	1026 m^3/hr
Exhaust gas back pressure max	76 mm Hg	76 mm Hg
Air flow – radiator*	1.5 m^3/s	1.5 m^3/s
Air intake – engine	407 m^3/hr	407 m^3/hr
Minimum air opening to room	0.7 sq m	0.7 sq m
Minimum discharge opening	0.5 sq m	0.5 sq m
Pusher fan head (duct allowance)	13 mm Wg*	13 mm Wg*
Total heat radiated to ambient (Engine)	18.4 kW	20.8 kW
Engine derating – altitude	4% per 300 m above 1000 m	4% per 300 m above 1000 m
Engine derating – temperature	2% per 11°C above 40°C	2% per 11°C above 40°C

In accordance with ISO 8528, BS5514.
Prime: Continuous running at variable load for unlimited periods with 10% overload available for 1 hour in any 12 hour period.
Standby: Continuous running at variable load for duration of an emergency.
Prime and standby ratings are outputs at 40°C (104°F) ambient temperature reference.
*Subject to factory verification.

6B Series Engines



Model	Engine	Length A mm	A1 mm	Width B1 mm	B mm	Height C mm	D mm	Set weight kg wet	Set weight kg dry	Sub base Tank. Dry Weight kg	Sub base Tank. Wet Weight kg
DGDH	6BT5.9G6	2047	1675	840	675	1337	200	1112	1075	150	320
DGDJ	6BT5.9G6	2162	1675	840	675	1337	200	1175	1138	150	320

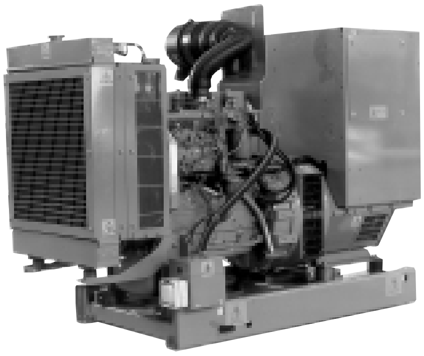
NOTE 1:
★ Battery tray extends out 260 mm from side – when fitted.
★ Dry and Wet weights of sets do NOT include fuel tank or contents.

Weights are **without** sub-base tank. Dimensions and weights are for **guidance** only.
Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

Technical Data

Power Generation

112 kW - 123 kW 50 Hz
6BTA Series Engine



Generating Sets – 50 Hz

6BTA5.9G2 – Set output 380 – 415V 50Hz	Standby	Prime
Ratings	123 kWe (154 kVA)	112 kWe (140 kVA)
Model	123 DGDE	112 DGDE
Engine Model	6BTA5.9G2	6BTA5.9G2
No of Cylinders	6	6
Aspiration	Turbocharged & Aftercooled	Turbocharged & Aftercooled
Gross Engine Power Output	145 kWm	126 kWm
BMEP	1945 kPa	1711kPa
Bore	102mm	102mm
Stroke	120mm	120mm
Piston Speed	7.2 m/s	7.2 m/s
Compression Ratio	16.5:1	16.5:1
Lube Oil Capacity	16.4 l	16.4 l
RPM	1500 RPM	1500 RPM
Overspeed Limit	2070 +/-50	2070 +/-50
Fuel Consumption Load	1/4 1/2 3/4 Full	1/4 1/2 3/4 Full
Fuel Consumption – L/hr	10 19 27 35	9 16 24 31
Optional Base Tank Capacity	200 l	200 l
Maximum Fuel Flow	201 l/hr	182 l/hr
Maximum Inlet Restriction	13.6 kPa	13.6 kPa
Maximum Return Restriction	68 kPa	68 kPa
Fan Load	3.7 kW	3.7 kW
Coolant Capacity (with radiator)	25.6 l	25.6 l
Coolant Flow Rate (engine jacket)	121 l/min	121 l/min
Heat Rejection to Eng Jacket Coolant	67 kW	58 kW
Heat Rejection to Aftercooler Coolant	40°C	40°C
Heat Rejection to Fuel	0.75 kW	0.75 kW
Heat Rejection to Ambient	22 kW	22 kW
Max Coolant Friction Head (JW)	28 kPa	28 kPa
Maximum Coolant Static Head	143 kPa	143 kPa
Max Top Tank Temp (engine jacket)	110°C	110°C
Combustion Air	9.1 m^3/min	8.4 m^3/min
Maximum Air Cleaner Restriction	6.2 kPa	6.2 kPa
Alternator Cooling Air	30.8 m^3/min	30.8 m^3/min
Radiator Cooling Air	138 m^3/min	138 m^3/min
Minimum Air Opening to Room (no attenuation)	0.9 m^2	0.9 m^2
Minimum Discharge Opening (no attenuation)	0.45 m^2	0.45 m^2
Max Static Restriction	125 Pa	125 Pa
Exhaust Gas Flow (Full Load)	25.3 m^3/min	22.6 m^3/min
Exhaust Gas Temperature	591°C	562°C
Maximum Back Pressure	10.2 kPa	10.2 kPa
Load Acceptance*	25% 50% 75% 100%	25% 50% 75% 100%
Volt Dip (%)	2.5 6 – –	– – – –
Recovery Time (sec)	1 1.5 – –	– – – –
Frequency Dip (%)	4 7 – –	– – – –
Recovery Time (sec)	1 1.5 – –	– – – –
Load Recovery	25% 50% 75% 100%	25% 50% 75% 100%
Volt Dip (%)	2.5 4 6.5 8	– – – –
Recovery Time (sec)	2 2 1 2	– – – –
Frequency Dip (%)	5 6 7.5 10	– – – –
Recovery Time (sec)	2 2.5 2 3	– – – –

*Typical figures only, base on an engine at full working temperature.
Load acceptance performance varies with site conditions.

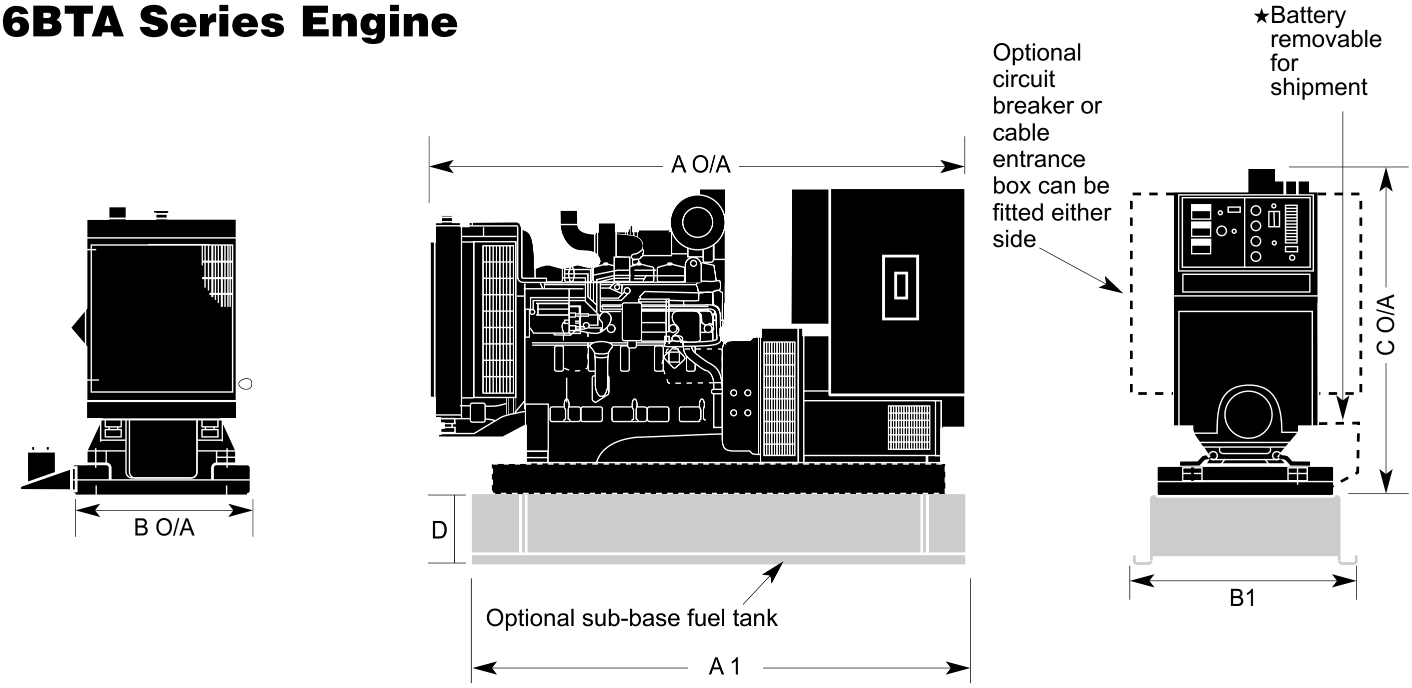
Rating Definitions

Standby Rating based on: Applicable for supplying power for the duration of the utility power outage. No overload capability is available for this rating. Under no condition is an engine allowed to operate in parallel with the public utility at the standby power rating. This rating should be applied only where reliable utility power is available.
A standby rated engine should be sized for a maximum of 70% average load factor and 200 hrs of operation per year. This includes a maximum of 1 hour in a 12 hour period at the standby power rating. Standby rating should never be applied except in true power outages.

Prime Rating based on: Prime Power is available continuously during the period of power outage in a variable load application. Variable load should not exceed a 70% average of the Prime Power rating during any 24 hour period. A 10% overload capability is available for a period of 1 hour within a 12 hour period of operation.

Power Generation

6BTA Series Engine



2000 Model	Engine	Length A mm	A1 mm	Width B1 mm	B mm	Height C mm	D mm	Set weight kg wet	Set weight kg dry	Sub base Tank. Dry Weight kg	Sub base Tank. Wet Weight kg
123 DGFE	6BTA5.9G2	2140	1675	840	700	1350	200	1093	1056	150	310

NOTE 1:
★ Battery tray extends out 260 mm from side – when fitted.
★ Dry and Wet weights of sets do NOT include fuel tank or contents.

Weights are **without** sub-base tank. Dimensions and weights are for **guidance** only.
Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

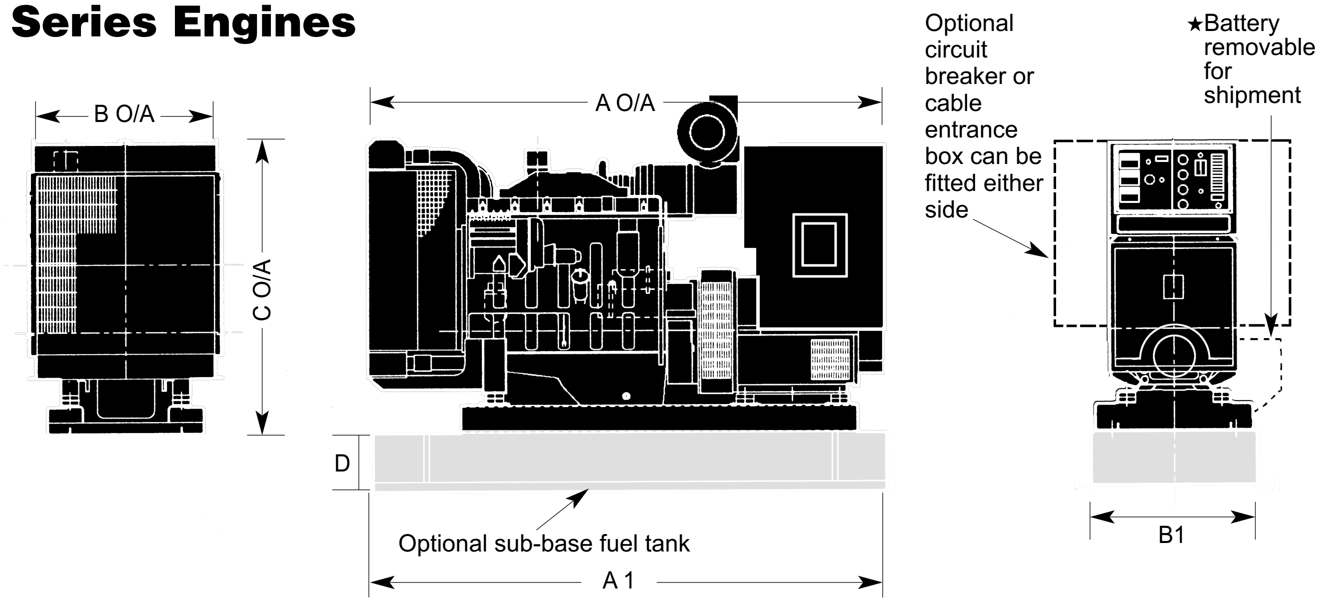
103 kW - 163 kW 50 Hz
6C Series Engines

Generating Sets – 50 Hz

Set output	380-440 V 50 Hz	380-440 V 50 Hz	380-440 V 50 Hz	380-440 V 50 Hz
Prime at 40°C ambient	103 kWe 129 kVA	122 kWe 153 kVA	148 kWe 185 kVA	163 kWe 204 kVA
Model (Prime)	103 DGEA	122 DGFA	148 DGFB	163 DGFC
Standby at 40°C ambient	116 kWe 145 kVA	136 kWe 170 kVA	163 kWe 204 kVA	N/A
Model (Standby)	116 DGEA	136 DGFA	163 DGFB	N/A
Engine Make	Cummins	Cummins	Cummins	Cummins
Model	6CT8.3G2	6CTA8.3G	6CTA8.3G	6CTAA8.3G
Cylinders	Six	Six	Six	Six
Engine build	In-line	In-line	In-line	In-line
Governor/Class	Mechanical	Mechanical	Mechanical	Mechanical
Aspiration and cooling	Turbocharged	Turbocharged Aftercooled	Turbocharged Aftercooled	Turbocharged Air to Air Aftercooled
Bore and stroke	114 mm x 135 mm	114 mm x 135 mm	114 mm x 135 mm	114 mm x 135 mm
Compression ratio	16.8	16.5:1	16.5:1	16.8:1
Cubic capacity	8.3 Litres	8.3 Litres	8.3 Litres	8.3 Litres
Starting/Min °C	Unaided/–12°C	Unaided/–12°C	Unaided/–12°C	Unaided/–12°C
Battery capacity	165 A/hr	165 A/hr	165 A/hr	165 A/hr
Nett Engine output – Prime	122 kWm	159 kWm	159 kWm	183 kWm
Nett at flywheel – Standby	135 kWm	176 kWm	176 kWm	203 kWm
Maximum load acceptance – single step	87 kWe	100 kWe	100 kWe	131 kWe
Speed	1500 rpm	1500 rpm	1500 rpm	1500 rpm
Alternator voltage regulation	±1.0%	±1.0%	±1.0%	±1.0%
Alternator insulation class	H	H	H	H
Single load step to NFPAII0	100%	100%	100%	100%
Fuel consumption (Prime) 100% load	30 l/hr	33 l/hr	40 l/hr	44.5 l/hr
Fuel consumption (Standby) 100% load	34 l/hr	36.6 l/hr	44 l/hr	49.9 l/hr
Lubrication oil capacity	23.8 Litres	23.8 Litres	23.8 Litres	23.8 Litres
Base fuel tank capacity – open set	330 Litres	330 Litres	330 Litres	330 Litres
Coolant capacity – radiator and engine	26 Litres	28 Litres	28 Litres	26 Litres
Exhaust temp – full load prime	521°C	627°C	638°C	583°C
Exhaust gas flow – full load prime	1522 m^3/hr	1716 m^3/hr	1850.4 m^3/hr	1955 m^3/hr
Exhaust gas back pressure max	76 mm Hg	76 mm Hg	76 mm Hg	75mm Hg
Air flow – radiator	3.5 m^3/s	3.1 m^3/s	3.1 m^3/s	3.6 m^3/s
Air intake – engine	568 m^3/hr	546 m^3/hr	586.8 m^3/hr	676 m^3/hr
Minimum air opening to room	0.9 sq m	0.9 sq m	0.9 sq m	0.9 sq m
Minimum discharge opening	0.6 sq m	0.6 sq m	0.6 sq m	0.6 sq m
Pusher fan head (duct allowance)	10 mm Wg	10 mm Wg	10 mm Wg	13 mm Wg
Total heat radiated to ambient (Engine)	27 kW	34 kW	35 kW	36 kW
Engine derating – altitude	4% per 300 m above 1525 m	4% per 300 m above 1525 m	4% per 300 m above 1525 m	4% per 300 m above 1000 m
Engine derating – temperature	1% per 5°C above 40°C	2% per 11°C above 40°C	2% per 11°C above 40°C	1.5% per 1°C above 30°C

In accordance with ISO 8528, BS5514.
Prime: Continuous running at variable load for unlimited periods with 10% overload available for 1 hour in any 12 hour period.
Standby: Continuous running at variable load for duration of an emergency.
Prime and standby ratings are outputs at 40°C (104°F) ambient temperature reference (with exception of Model CP200-5 which is 30°C).

6C Series Engines



Model	Engine	Length A mm	A1 mm	Width B1 mm	B mm	Height C mm	D mm	Set weight kg wet	Set weight kg dry	Sub base Tank. Dry Weight kg	Sub base Tank. Wet Weight kg
DGEA	6CT8.3G2	2332	2200	840	831	1412	250	1500	1448	210	490
DGFA	6CTA8.3G2	2339	2200	840	831	1412	250	1650	1594	210	490
DGFB	6CTA8.3G	2429	2200	840	831	1412	250	1760	1704	210	490
DGFC	6CTAA8.3G	2555	2200	840	1070	1426	250	1800	1744	210	490

NOTE 1:
★ Battery tray extends out 260 mm from side – when fitted.
★ Dry and Wet weights of sets do NOT include fuel tank or contents.

Weights are **without** sub-base tank. Dimensions and weights are for **guidance** only.
Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

184 kW - 200 kW 50 Hz
6CTAA Series Engine

Generating Sets – 50 Hz

6CTAA8.3G2 – Set output 380 – 440V 50Hz	Standby				Prime			
Ratings	200 kWe (250 kVA)				184 kWe (230 kVA)			
Model	200 DGFE				184 DGFE			
Engine Model	6CTAA8.3G2				6CTAA8.3G2			
No of Cylinders	6				6			
Aspiration	Turbocharged & Aftercooled				Turbocharged & Aftercooled			
Gross Engine Power Output	231 kWm				209 kWm			
BMEP	2300 kPa				2230kPa			
Bore	114mm				114mm			
Stroke	135mm				135mm			
Piston Speed	8.1 m/s				8.1 m/s			
Compression Ratio	16.7:1				16.7:1			
Lube Oil Capacity	18.9 l				18.9 l			
RPM	1500 RPM				1500 RPM			
Overspeed Limit	2070 +/-50				2070 +/-50			
Fuel Consumption Load	1/4	1/2	3/4	Full	1/4	1/2	3/4	Full
l/hr	15	28	42	57	14	25	38	51
Optional Base Tank Capacity	330 l				330 l			
Maximum Fuel Flow	126 l/hr				126 l/hr			
Maximum Inlet Restriction	13.6 kPa				13.6 kPa			
Maximum Return Restriction	34 kPa				34 kPa			
Fan Load	6.3 kW				6.3 kW			
Coolant Capacity (with radiator)	32 l				32 l			
Coolant Flow Rate (engine jacket)	200 l/min				200 l/min			
Heat Rejection to Eng Jacket Coolant	80 kW				72 kW			
Heat Rejection to Aftercooler Coolant	40°C				40°C			
Heat Rejection to Fuel	n/a				n/a			
Heat Radiated to Room	24 kW				22 kW			
Max Coolant Friction Head (JW)	28 kPa				28 kPa			
Maximum Coolant Static Head	187 kPa				187 kPa			
Max Top Tank Temp (engine jacket)	110°C				110°C			
Combustion Air	15.4 m^3/min				15.3 m^3/min			
Maximum Air Cleaner Restriction	6.2 kPa				6.2 kPa			
Alternator Cooling Air	30.8 m^3/min				30.8 m^3/min			
Radiator Cooling Air	246 m^3/min				246 m^3/min			
Minimum Air Opening to Room (no attenuation)	1.16 m^2				1.16 m^2			
Minimum Discharge Opening (no attenuation)	0.58 m^2				0.58 m^2			
Max Static Restriction	125 Pa				125 Pa			
Exhaust Gas Glow (Full Load)	42.2 m^3/min				40.9 m^3/min			
Exhaust Gas Temperature	586°C				565°C			
Maximum Back Pressure	10.2 kPa				10.2 kPa			

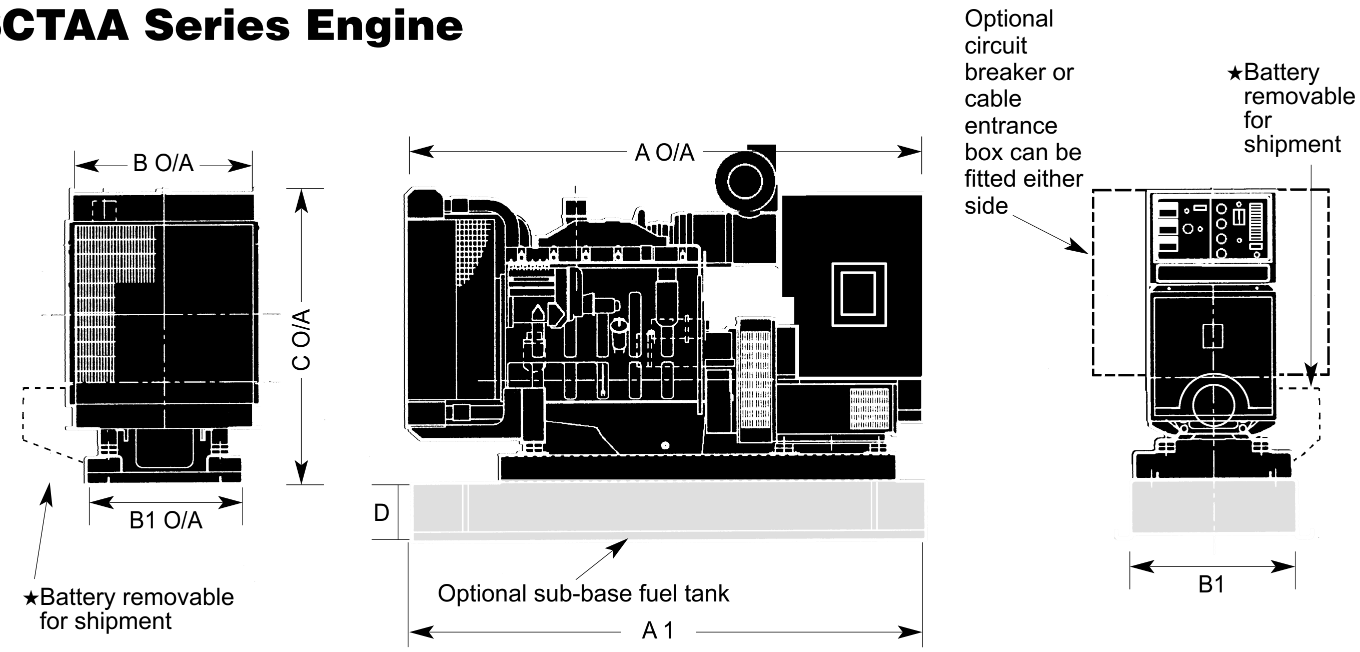
Rating Definitions

Standby Rating based on: Applicable for supplying power for the duration of the utility power outage. No overload capability is available for this rating. Under no condition is an engine allowed to operate in parallel with the public utility at the standby power rating. This rating should be applied only where reliable utility power is available. A standby rated engine should be sized for a maximum of 70% average load factor and 200 hrs of operation per year. This includes a maximum of 1 hour in a 12 hour period at the standby power rating. Standby rating should never be applied except in true power outages.

Prime Rating based on: Prime Power is available continuously during the period of power outage in a variable load application. Variable load should not exceed a 70% average of the Prime Power rating during any 24 hour period. A 10% overload capability is available for a period of 1 hour within a 12 hour period of operation.

Power Generation

6CTAA Series Engine



Model	Engine	Length A mm	A1 mm	Width B1 mm	B mm	Height C mm	D mm	Set weight kg wet	Set weight kg dry	Sub base Tank. Dry Weight kg	Sub base Tank. Wet Weight kg
DGFE	6CTAA8.3G2	2590	2200	840	995	1400	250	1805	1746	210	490

NOTE 1:
★ Battery tray extends out 260 mm from side – when fitted.
★ Dry and Wet weights of sets do NOT include fuel tank or contents.

Weights are **without** sub-base tank. Dimensions and weights are for **guidance** only.
Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

186 kW - 223 kW 50 Hz
LTA10 Series Engines

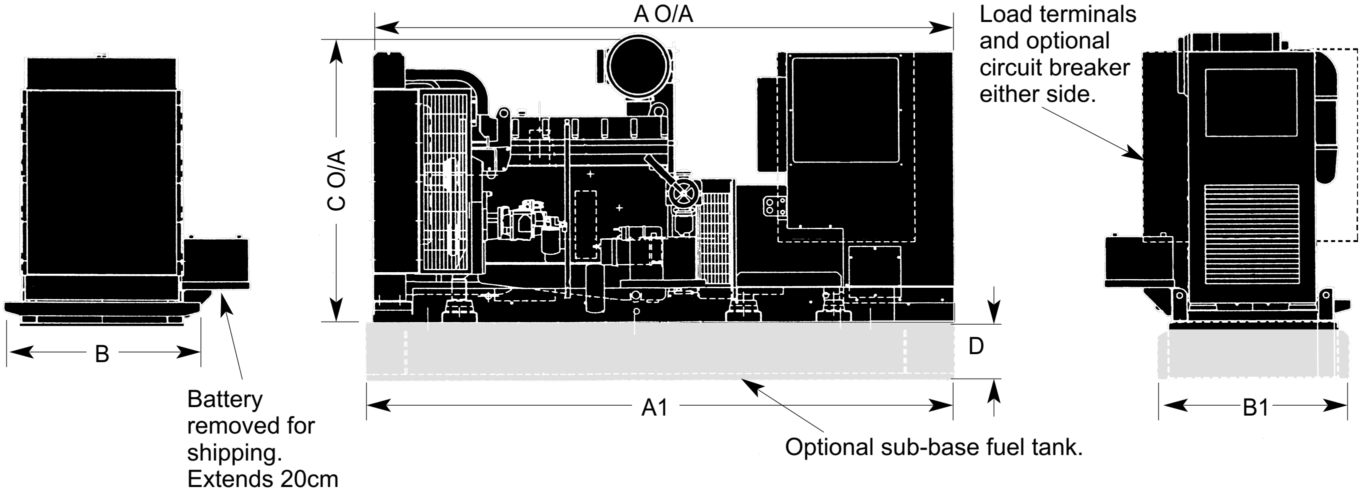
Generating Sets – 50 Hz

Set output	380-415 V 50 Hz	380-415 V 50 Hz
Prime at 40°C ambient	186 kWe 233 kVA	202 kWe 253 kVA
Model (Prime)	186 DFAB	202 DFAC
Standby at 40°C ambient	207 kWe 259 kVA	223 kWe 279 kVA
Model (Standby)	207 DFAB	223 DFAC
Engine Make	Cummins	Cummins
Model	LTA10G2	LTA10G3
Cylinders	Six	Six
Engine build	In-line	In-line
Governor/Class	Electronic/A1	Electronic/A1
Aspiration and cooling	Turbo Aftercooled	Turbo Aftercooled
Bore and stroke	125 mm x 136 mm	125 mm x 136 mm
Compression ratio	16.0:1	16.0:1
Cubic capacity	10 Litres	10 Litres
Starting/Min °C	Unaided/–1°C	Unaided/–1°C
Battery capacity	127 A/hr	127 A/hr
Engine output – Prime	203 kWm	218 kWm
Nett at flywheel – Standby	225 kWm	240 kWm
Maximum load acceptance – single step	120 kWe	120 kWe
Speed	1500 rpm	1500 rpm
Alternator voltage regulation	±1.0%	±1.0%
Alternator insulation class	H	H
Single load step to NFPAII0	100%	100%
Fuel consumption (Prime) 100% load	48.4 l/hr	51.1 l/hr
Fuel consumption (Standby) 100% load	53.4 l/hr	55.6 l/hr
Lubrication oil capacity	36 Litres	36 Litres
Base fuel tank capacity – open set	675 Litres	675 Litres
Coolant capacity – radiator and engine	53 Litres	53 Litres
Exhaust temp – full load prime	502°C	510°C
Exhaust gas flow – full load prime	2192 m^3/hr	2329.2 m^3/hr
Exhaust gas back pressure max	76 mm Hg	76 mm Hg
Air flow – radiator (40°C) ambient*	5.6 m^3/s	4.5 m^3/s
Pusher fan head (duct allowance) 40°C*	13 mm Wg	13 mm Wg
Air intake – engine	817 m^3/hr	848 m^3/hr
Air flow – radiator (50°C)*	5.0 m^3/s	3.8 m^3/s
Pusher fan head (duct allowance) 40°C and 50°C*	13 mm Wg	13 mm Wg
Total heat radiated to ambient	41 kW	46 kW
Engine derating – altitude	4% per 300 m above 1525 m	4% per 300 m above 1525 m
Engine derating – temperature	2% per 11°C above 40°C	2% per 11°C above 40°C

In accordance with ISO 8528, BS5514.
Prime: Continuous running at variable load for unlimited periods with 10% overload available for 1 hour in any 12 hour period.
Standby: Continuous running at variable load for duration of an emergency.
Prime and standby ratings are outputs at 40°C (104°F) reference.

Power Generation

LTA10 Series Engines



Model	Engine	Dimensions and Weights (mm/kg)						Set Weight kg Dry	Set Weight kg Wet	Tank (dry) Weight kg	Tank (wet) Weight kg
		A	A1	B	B1	C	D				
DFAB	LTA10G2	2980	3338	1048	1050	1644	300	2230	2300	445	1085
DFAC	LTA10G3	2980	3338	1048	1050	1644	300	2230	2300	445	1085

Set weights are **without** sub-base tank.
Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

Power Generation

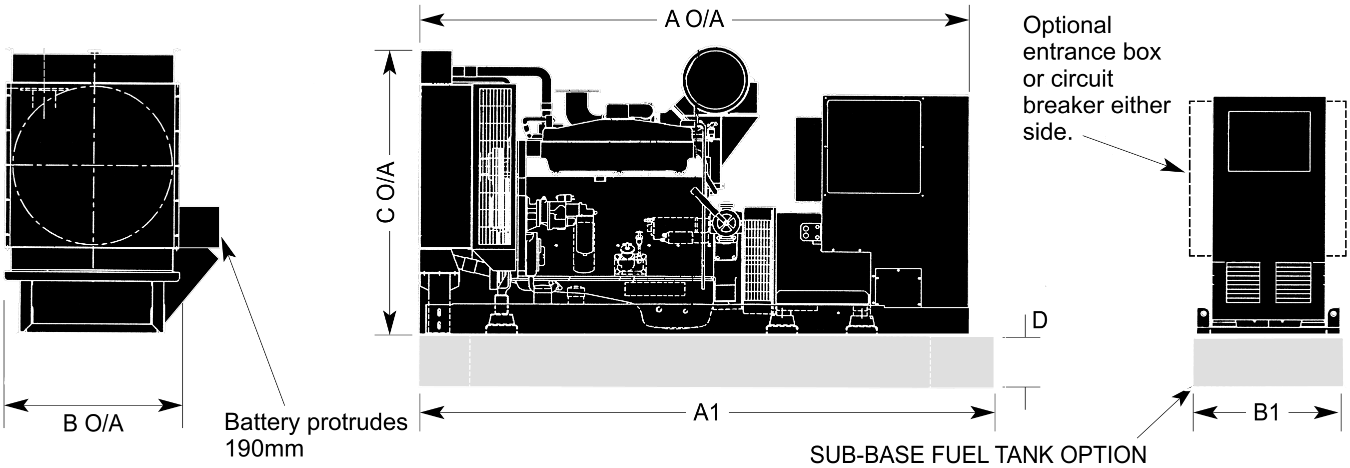
250 kW - 340 kW 50 Hz
NT855 Series Engines

Generating Sets – 50 Hz

Set output	380-440 V 50 Hz	380-440 V 50 Hz	380-440 V 50 Hz	380-440 V 50 Hz
Prime at 40°C ambient	–	252 kWe 315 kVA	280 kWe 350 kVA	–
Model (Prime)	–	252 DFBH	280 DFCC	–
Standby at 40°C ambient	250 kWe 313 kVA	280 kWe 350 kVA	312 kWe 390 kVA	340 kWe 425 kVA
Model (Standby)	250 DFBF	280 DFBH	312 DFCC	340 DFCE
Engine Make	Cummins	Cummins	Cummins	Cummins
Model	NT855G6	NT855G6	NTA855G4	NTA855G6
Cylinders	Six	Six	Six	Six
Engine build	In-line	In-line	In-line	In-line
Governor/Class	Electronic/A1	Electronic/A1	Electronic/A1	Electronic/A1
Aspiration and cooling	Turbocharged	Turbocharged	Turbo Aftercooled	Turbo Aftercooled
Bore and stroke	140 mm x 152 mm	140 mm x 152 mm	140 mm x 152 mm	140 mm x 152 mm
Compression ratio	14.0:1	14.0:1	14.0:1	14.0:1
Cubic capacity	14 Litres	14 Litres	14 Litres	14 Litres
Starting/Min °C	Unaided/4°C	Unaided/4°C	Unaided/–7°C	Unaided/–7°C
Battery capacity	127 A/hr	127 A/hr	127 A/hr	127 A/hr
Nett Engine output – Prime	–	272 kWm	309 kWm	–
Nett at flywheel – Standby	302 kWm	302 kWm	342 kWm	361 kWm
Maximum load acceptance single step	172 kWe	172 kWe	175 kWe	175 kWe
Speed	1500 rpm	1500 rpm	1500 rpm	1500 rpm
Alternator voltage regulation	±1.0%	±1.0%	±1.0%	±1.0%
Alternator insulation class	H	H	H	H
Single load step to NFPAII0	100%	100%	100%	100%
Fuel consumption (Prime) 100% load	–	69 l/hr	76 l/hr	–
Fuel consumption (Standby) 100% load	67 l/hr	76 l/hr	84 l/hr	91 l/hr
Lubrication oil capacity	38.6 Litres	38.6 Litres	38.6 Litres	38.6 Litres
Base fuel tank capacity – open set	800 Litres	800 Litres	800 Litres	800 Litres
Coolant capacity – radiator and engine	63.9 Litres	63.9 Litres	69.8 Litres	69.8 Litres
Exhaust temp – full load prime	574°C	574°C	524°C	487°C
Exhaust gas flow – full load prime	3855.6 m^3/hr	3855.6 m^3/hr	4060.8 m^3/hr	4723 m^3/hr
Exhaust gas back pressure max	76 mm Hg	76 mm Hg	76 mm Hg	76 mm Hg
Air flow – radiator (40°C)	7.6 m^3/s	7.6 m^3/s	6.4 m^3/s	7.6 m^3/s
Pusher fan head (duct allowance) 40°C	13 mm Wg	13 mm Wg	13 mm Wg	13 mm Wg
Air intake – engine	1299.6 m^3/hr	1299 m^3/hr	1468.8 m^3/hr	1854 m^3/hr
Air flow – radiator (50°C)	7.6 m^3/s	7.6 m^3/s	8.3 m^3/s	8.3 m^3/s
Pusher fan head (duct allowance) 50°C	13 mm Wg	13 mm Wg	13 mm Wg	13 mm Wg
Total heat radiated to ambient	57 kW	57 kW	65 kW	81 kW
Engine derating – altitude	4% per 300 m above 1525 m	4% per 300 m above 1525 m	4% per 300 m above 1525 m	4% per 300 m above 1525 m
Engine derating – temperature	2% per 11°C above 40°C	2% per 11°C above 40°C	2% per 11°C above 40°C	2% per 11°C above 40°C

In accordance with ISO 8528, BS5514.
Prime: Continuous running at variable load for unlimited periods with 10% overload available for 1 hour in any 12 hour period.
Standby: Continuous running at variable load for duration of an emergency.

NT855 Series Engines



Model	Engine	A	Dimensions and Weights (mm/kg) A1	B	B1	C	D	Set Weight kg Dry	Set Weight kg Wet	Tank Weight kg (dry)	Tank Weight kg (wet)
DFBF	NT855G6	3196	3338	990	1048	1777	300	2983	3100	445	1085
DFBH	NT855G6	3286	3338	990	1048	1777	300	3133	3230	445	1085
DFCC	NTA855G4	3286	3338	990	1048	1777	300	3178	3275	445	1085
DFCE	NTA855G6	3304	3338	990	1048	1777	300	3291	3388	445	1085

Set weights are **without** sub-base tank.
Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

364 kW - 440 kW 50 Hz
QSX15 Series Engine

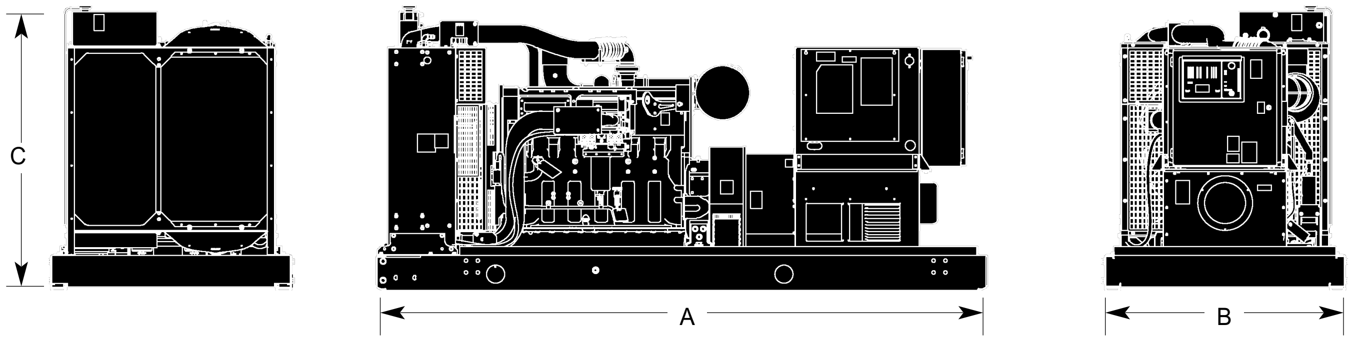
QSX15G8 Generating Sets – 50 Hz

	Prime				Standby				Prime				Standby			
Model	364 DFEJ				400 DFEJ				400 DFEK				440 DFEK			
Ratings	364 kW				400 kW				400 kW				440 kW			
	455 kVA				500 kVA				500 kVA				550 kVA			
Engine Model	QSX15G8				QSX15G8				QSX15G8				QSX15G8			
Aspiration: Turbo-charged with air-to-air aftercooling	Yes				Yes				Yes				Yes			
Gross Engine Power	451 kWm				500 kWm				451 kWm				500 kWm			
Break Mean Effective Pressure	2137 kPa				2344 kPa				2344 kPa				2571 kPa			
Bore	137 mm				137 mm				137 mm				137 mm			
Stroke	169 mm				169 mm				169 mm				169 mm			
Piston Speed	8.4 m/s				8.4 m/s				8.4 m/s				8.4 m/s			
Compression Ratio	17:1				17:1				17:1				17:1			
Lubricating Oil Capacity	83 Litres				83 Litres				83 Litres				83 Litres			
Overspeed Limit	2150 rpm ±50				2150 rpm ±50				2150 rpm ±50				2150 rpm ±50			
Dry Weight	4082 kg				4082 kg				4309 kg				4309 kg			
Wet Weight	4218 kg				4218 kg				4445 kg				4445 kg			
Fuel Consumption Load	1/4	1/2	3/4	Full	1/4	1/2	3/4	Full	1/4	1/2	3/4	Full	1/4	1/2	3/4	Full
Fuel Consumption L/hr	32	51	71	91	34	55	77	99	34	55	77	99	36	60	84	108
Maximum Fuel Flow	435 L/hr				435 L/hr				435 L/hr				435 L/hr			
Maximum Fuel Inlet Restriction	127 mm Hg				127 mm Hg				127 mm Hg				127 mm Hg			
Maximum Fuel Return Restriction	77 mm Hg				77 mm Hg				77 mm Hg				77 mm Hg			
Fan Load	23 kW				23 kW				23 kW				23 kW			
Coolant Capacity	58 Litres				58 Litres				58 Litres				58 Litres			
Coolant Flow	394 L/Min				394 L/Min				394 L/Min				394 L/Min			
Heat Rejection to Eng Jacket Coolant	129 kW				141 kW				141 kW				156 kW			
Heat Rejected to Ambient	51 kW				56 kW				56 kW				64 kW			
Combustion Air	30 m^3/min				32 m^3/min				32 m^3/min				34 m^3/min			
Maximum Air Cleaner Restriction	6.2 kPa				6.2 kPa				6.2 kPa				6.2 kPa			
Alternator Cooling Air	52 m^3/min				52 m^3/min				52 m^3/min				52 m^3/min			
Radiator Cooling Air	679 m^3/min				679 m^3/min				679 m^3/min				679 m^3/min			
Minimum Air Opening to Room	2.3 m^2				2.3 m^2				2.3 m^2				2.3 m^2			
Minimum Discharge Opening	1.6 m^2				1.6 m^2				1.6 m^2				1.6 m^2			
Maximum Static Restriction	13 mm Wg				13 mm Wg				13 mm Wg				13 mm Wg			
Exhaust Gas Flow (Full Load)	73 m^3/min				79 m^3/min				79 m^3/min				87 m^3/min			
Exhaust Gas Temperature	474 °C				487 °C				487 °C				507 °C			
Maximum Exhaust Back Pressure	6.7 kPa				6.7 kPa				6.7 kPa				6.7 kPa			
Derate	RTF				RTF				RTF				RTF			

Typical figures only, based on an engine at full working temperature.
Load acceptance performance varies with site conditions.

Ratings
Standby
Applicable for supplying emergency power for the duration of normal power interruption. No sustained overload capability is available for this rating. Nominally Rated (equivalent to fuel stop power in accordance with ISO 3046).
Prime
Applicable for supplying power in lieu of commercially purchased power. Prime power is the maximum power available at a variable load for an unlimted number of hours. A 10% overload capability is available for limited time. Nominally rated.

QSX15 Series Engine



Model	Engine	Dimensions and Weights (mm/kg)			Set Weight kg Dry	Set Weight kg Wet	Tank Weight kg (dry)	Tank Weight kg (wet)
		A	B	C				
DFEJ	QSX15G8	3868	1524	1534	4309	4445	RTF	RTF
DFEK	QSX15G8	3868	1524	1534	4309	4445	RTF	RTF

RTF = Refer to Factory.

Set weights are **without** sub-base tank.
Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

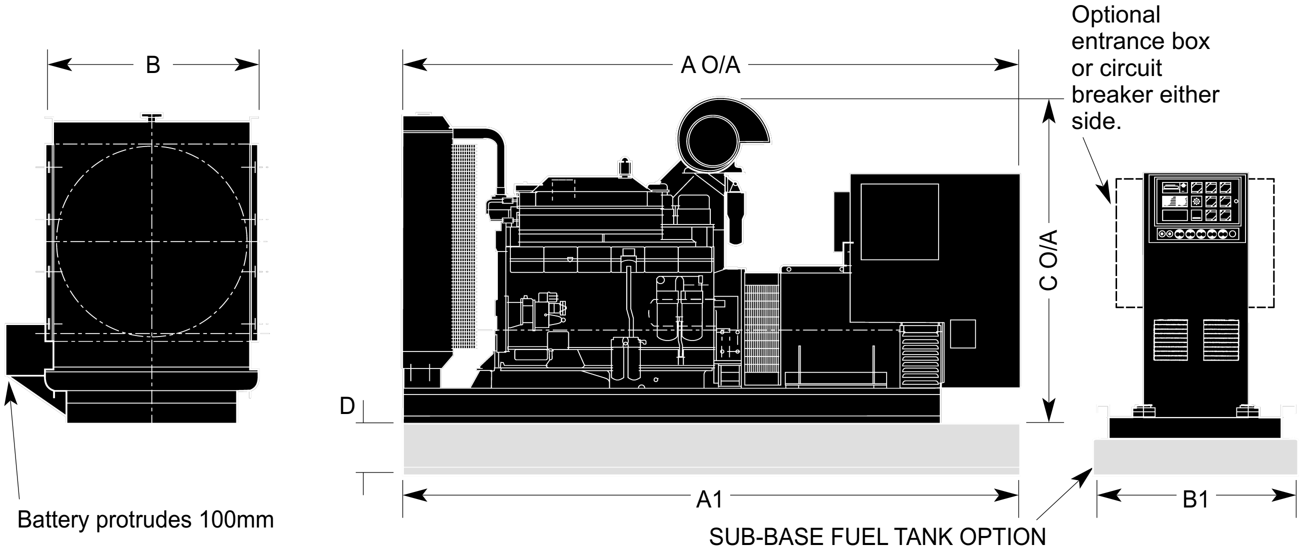
345 kW - 461 kW 50 Hz
K19 Series Engines

Generating Sets – 50 Hz

Set output	380-440 V 50 Hz	380-440 V 50 Hz	380-440 V 50 Hz
Prime at 40°C ambient	345 kWe 431 kVA	360 kWe 450 kVA	409 kWe 511 kVA
Model (Prime)	345 DFEC	360 DFEL	409 DFED
Standby at 40°C ambient	–	400 kWe 500 kVA	461 kWe 576 kVA
Model (Standby)	–	400 DFEL	461 DFED
Engine Make	Cummins	Cummins	Cummins
Model	KTA19G3	KTA19G3	KTA19G4
Cylinders	Six	Six	Six
Engine build	In-line	In-line	In-line
Governor/Class	Electronic/A1	Electronic/A1	Electronic/A1
Aspiration and cooling	Turbo Aftercooled	Turbo Aftercooled	Turbo Aftercooled
Bore and stroke	159 mm x 159 mm	159 mm x 159 mm	159 mm x 159 mm
Compression ratio	13.9:1	13.9:1	13.9:1
Cubic capacity	18.9 Litres	18.9 Litres	18.9 Litres
Starting/Min °C	Unaided/7°C	Unaided/7°C	Unaided/0°C
Battery capacity	190 A/hr	190 A/hr	190 A/hr
Nett Engine output – Prime	384 kWm	384 kWm	429 kWm
Nett at flywheel – Standby	NA	429 kWm	485 kWm
Maximum load acceptance single step	250 kWe	250 kWe	250 kWe
Speed	1500 rpm	1500 rpm	1500 rpm
Alternator voltage regulation	±1.0%	±1.0%	±1.0%
Alternator insulation class	H	H	H
Single load step to NFPAII0	100%	100%	100%
Fuel consumption (Prime) 100% load	91 l/hr	97 l/hr	107 l/hr
Fuel consumption (Standby) 100% load	100 l/hr	107 l/hr	121 l/hr
Lubrication oil capacity	50 Litres	50 Litres	50 Litres
Base fuel tank capacity – open set	1200 Litres	1200 Litres	1200 Litres
Coolant capacity – radiator and engine	91 Litres	91 Litres	91 Litres
Exhaust temp – full load prime	524°C	524°C	538°C
Exhaust gas flow – full load prime	4842 m^3/hr	4842 m^3/hr	5162 m^3/hr
Exhaust gas back pressure max	76 mm Hg	76 mm Hg	76 mm Hg
Air flow – radiator (40°C ambient)	13.7 m^3/s	13.7 m^3/s	13.7 m^3/s
Pusher fan head (duct allowance) 40°C	13 mm Wg	13 mm Wg	13 mm Wg
Air intake – engine	1749 m^3/hr	1749.6 m^3/hr	1912 m^3/hr
Air flow – radiator (50°C)	11.5 m^3/s	11.5 m^3/s	11.5 m^3/s
Pusher fan head (duct allownace) 50°C	13 mm Wg	13 mm Wg	13 mm Wg
Total heat radiated to ambient	78 kW	79 kW	88 kW
Engine derating – altitude	4% per 300 m above 1525 m	4% per 300 m above 1525 m	4% per 300 m above 2280 m
Engine derating – temperature	2% per 11°C above 40°C	2% per 11°C above 40°C	2% per 11°C above 40°C

In accordance with ISO 8528, BS5514.
Prime: Continuous running at variable load for unlimited periods with 10% overload available for 1 hour in any 12 hour period.
Standby: Continuous running at variable load for duration of an emergency.

K19 Series Engines



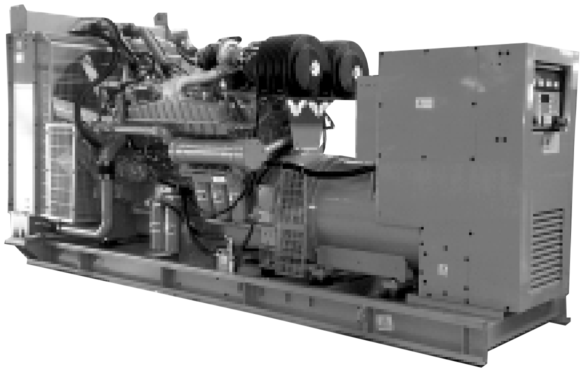
Model	Engine	Dimensions and Weights (mm/kg)						Set Weight kg Dry	Set Weight kg Wet	Tank Weight kg (dry)	Tank Weight kg (wet)
		A	A1	B	B1	C	D				
DFEC	KTA19G3	3490	3875	1266	1350	1830	300	4136	4270	580	1580
DFEL	KTA19G3	3490	3875	1266	1350	1830	300	4136	4270	580	1580
DFED	KTA19G4	3490	3875	1266	1350	1830	300	4276	4410	580	1580

Set weights are **without** sub-base tank.
Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

Technical Data

Power Generation

460 kW - 565 kW 50 Hz
VTA28 Series Engines

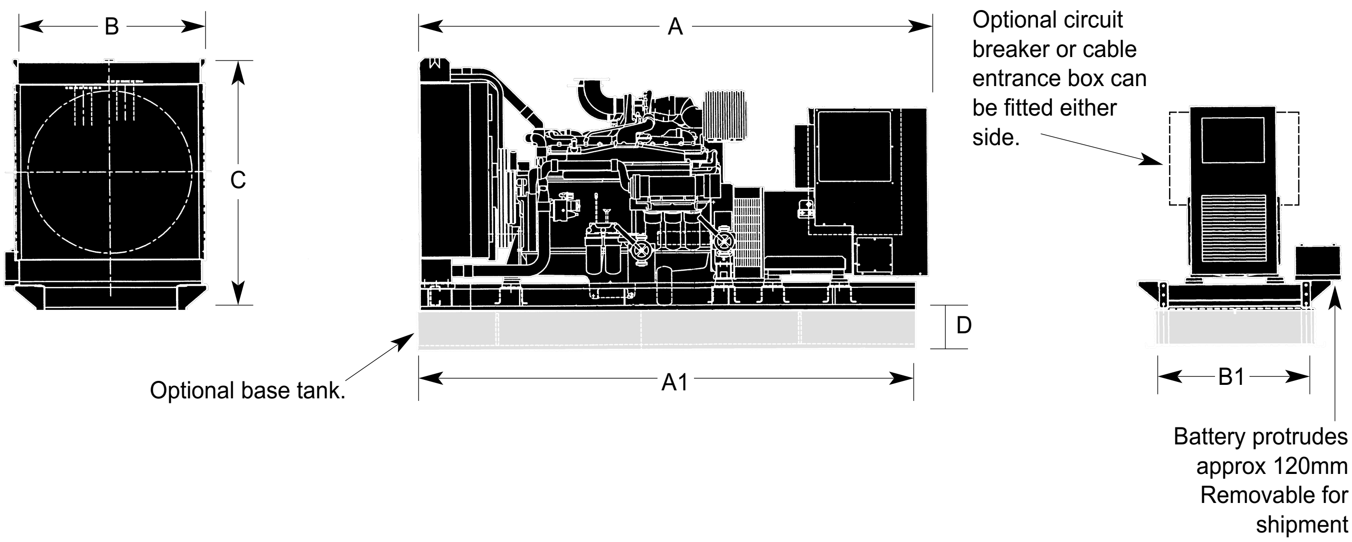


Generating Sets – 50 Hz

Set output	380-440 V 50 Hz	380-440 V 50 Hz
Prime at 40°C ambient	460 kWe 575 kVA	512 kWe 640 kVA
Model (Prime)	460 DFGA	512 DFGB
Standby at 40°C ambient	509 kWe 636 kVA	565 kWe 706 kVA
Model (Standby)	509 DFGA	565 DFGB
Engine Make	Cummins	Cummins
Model	VTA28G5	VTA28G5
Cylinders	Twelve	Twelve
Engine build	Vee	Vee
Governor / Class	Electronic / A1	Electronic / A1
Aspiration and cooling	Turbo Aftercooled	Turbo Aftercooled
Bore and stroke	140 mm x 152 mm	140 mm x 152 mm
Compression ratio	13.0:1	13.0:1
Cubic capacity	28 Litres	28 Litres
Starting / Min °C	Unaided / 4°C	Unaided / 4°C
Battery capacity	254 A/hr	254 A/hr
Nett Engine output – Prime	548 kWm	548 kWm
Nett Engine output – Standby	604 kWm	604 kWm
Maximum load acceptance – single step	340 kWe	340 kWe
Speed	1500 rpm	1500 rpm
Alternator voltage regulation	±1.0%	±1.0%
Alternator insulation class	H	H
Single load step to NFPA 110	100%	100%
Fuel consumption (Prime) 100% load	124 l/hr	140 l/hr
Fuel consumption (Standby) 100% load	137 l/hr	154 l/hr
Lubrication oil capacity	83 Litres	83 Litres
Base fuel tank capacity – open set	1200 Litres	1200 Litres
Coolant capacity – radiator and engine	166 Litres	166 Litres
Exhaust temp – full load prime	493°C	493°C
Exhaust gas flow – full load prime	7153 m^3/hr	7153.2 m^3/hr
Exhaust gas back pressure max	76 mm Hg	76 mm Hg
Air flow – radiator (40°C ambient)	*13.7 m^3/s	*13.7 m^3/s
Pusher fan head (duct allowance) 40°C	*19 mm Wg	*19 mm Wg
Air intake – engine	2976.6 m^3/hr	2976.6 m^3/hr
Air flow – radiator (50°C)	*13.1 m^3/s	*13.1 m^3/s
Pusher fan head (duct allowance) 50°C	*19 mm Wg	*19 mm Wg
Total heat radiated to ambient	112 kW	114 kW
Engine derating – altitude	4% per 300 m above 1220 m	4% per 300 m above 1220 m
Engine derating – temperature	2% per 11°C above 40°C	2% per 11°C above 40°C

In accordance with ISO 8528, BS5514.
Prime: Continuous running at variable load for unlimited periods with 10% overload available for 1 hour in any 12 hour period.
Standby: Continuous running at variable load for duration of an emergency.
*Subject to factory verification. Engine production tolerance ±5%.

VTA28 Series Engines



Model	Engine	Dimensions and Weights (mm/kg)						Set Weight	Set Weight	Tank Weight	Tank Weight
		A	A1	B1	B	C	D	kg Dry	kg Wet	kg (dry)	kg (wet)
460 DFGA	VTA28G5	3825	3875	1350	1423	1942	300	5355	5665	580	1580
512 DFGB	VTA28G5	3900	3875	1350	1423	1942	300	5730	6040	580	1580

Set weights are **without** sub-base tank.

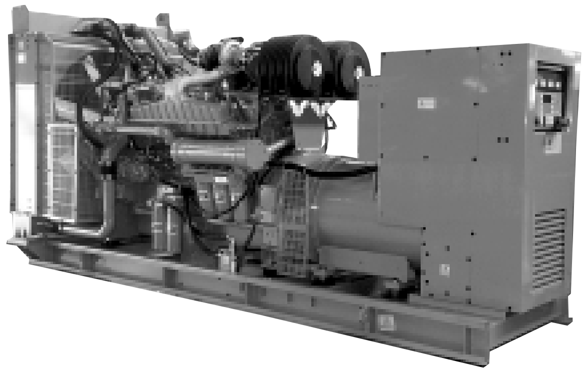
Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application.

Specifications may change without notice.

Technical Data

Power Generation

600 kW - 660 kW 50 Hz VTA28G6 Series Engine



Generating Sets – 50 Hz

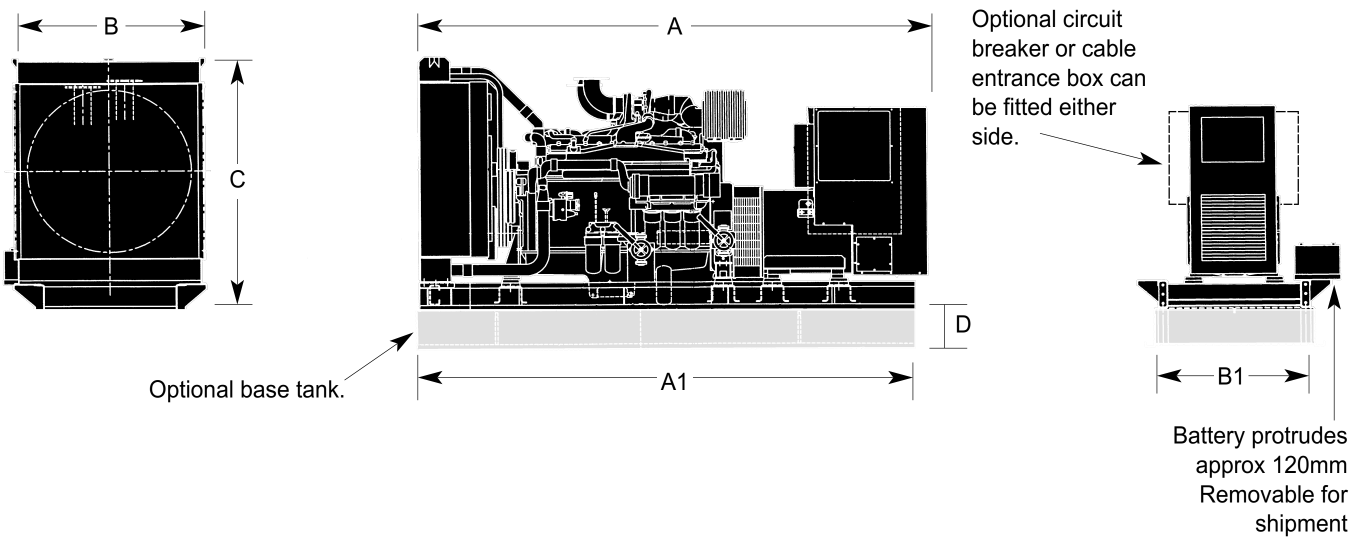
VTA28G6 – **See output 400 V 50Hz	Standby	Prime
Ratings	660kWe (825 kVA)	600kWe (750 kVA)
Model	660 DFGD	600 DFGD
Engine Model	VTA28G6	VTA28G6
No of Cylinders	12	12
Aspiration	Turbocharged & Aftercooled	Turbocharged & Aftercooled
Gross Engine Power Output	722 kWm	656 kWm
BMEP	2062 kPa	1874 kPa
Bore	140 mm	140 mm
Stroke	152 mm	152 mm
Piston Speed m/sec	7.6 m/s	7.6 m/s
Compression Ratio	13.0:1	13.0:1
Lube Oil Capacity	83 l	83 l
RPM	1500 RPM	1500 RPM
Overspeed Limit	2070 +/-50 RPM	2070 +/-50 RPM
Fuel Consumption Load	1/4 1/2 3/4 Full	1/4 1/2 3/4 Full
Fuel Consumption – L/hr	40 81 121 162	36 73 110 147
Optional Base Tank Capacity l	1200 l	1200 l
Maximum Fuel Flow	448 l/hr	448 l/hr
Maximum Inlet Restriction	27 kPa	27 kPa
Maximum Return Restriction	22 kPa	22 kPa
Fan Load	19 kW	19 kW
Coolant Capacity (with radiator)	162 l	162 l
Coolant Flow Rate (engine jacket)	732 l/min	732 l/min
Heat Rejection to Eng Jacket Coolant	575 kW	575 kW
Heat Rejection to Aftercooler Coolant	NA	NA
Heat Rejection to Fuel	NA	NA
Heat Radiated to Ambient	90 kW	90 kW
Max Coolant Friction Head	55 kPa	55 kPa
Maximum Coolant Static Head	18.3 kPa	18.3 kPa
Max Top Tank Temp (engine jacket)	104°C	100°C
Combustion Air	55 m^3/min	49 m^3/min
Maximum Air Cleaner Restriction	85 kPa	85 kPa
Alternator Cooling Air	97 m^3/min	97 m^3/min
Radiator Cooling Air	750 m^3/min	750 m^3/min
Minimum Air Opening to Room (no attenuation)	4.1 m^2	4.1 m^2
Minimum Discharge Opening (no attenuation)	3.2 m^2	3.2 m^2
Max Static Restriction	13 mm Hg	13 mm Hg
Exhaust Gas Flow (Full Load)	132 m^3/min	120 m^3/min
Exhaust Gas Temperature	489°C	464°C
Maximum Back Pressure	10.1 kPa	10.2 kPa
Load Acceptance*	25% 50% 75% 100%	25% 50% 75% 100%
Volt Dip (%)	4 11 18 30	
Recovery Time (sec)	1 1.5 1.5 4	
Frequency Dip (%)	3 4.5 6 9	
Recovery Time (sec)	1.5 1.5 3 6	
Load Recovery	25% 50% 75% 100%	25% 50% 75% 100%
Volt Dip (%)	4 9 15 20	
Recovery Time (sec)	1.5 2 2 3	
Frequency Dip (%)	2.5 3.5 4 6.5	
Recovery Time (sec)	2 2.5 2.5 2.5	

*Typical figures only, based on an engine at full working temperature.
Load acceptance performance varies with site conditions.
**Refer to factory for other voltage output

Rating Definitions

Standby Rating based on: Applicable for supplying power for the duration of the utility power outage. No overload capability is available for this rating. Under no condition is an engine allowed to operate in parallel with the public utility at the standby power rating. This rating should be applied only where reliable utility power is available.
A standby rated engine should be sized for a maximum of 70% average load factor and 200 hrs of operation per year. This includes a maximum of 1 hour in a 12 hour period at the standby power rating. Standby rating should never be applied except in true power outages.
Prime Rating based on: Prime Power is available continuously during the period of power outage in a variable load application. Variable load should not exceed a 70% average of the Prime Power rating during any 24 hour period. A 10% overload capability is available for a period of 1 hour within a 12 hour period of operation.

VTA28G6 Series Engine



Model	Engine	New Dimensions and Weights (mm/kg)						Set Weight kg Dry	Set Weight kg Wet	Tank Weight kg (dry)	Tank Weight kg (wet)
		A	A1	B1	B	C	D				
DFGD	VTA28G6	3900	3875	1350	1423	1942	300	6389	671	580	1580

*Subject to factory confirmation.

Set weights are **without** sub-base tank.

Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application.

Specifications may change without notice.

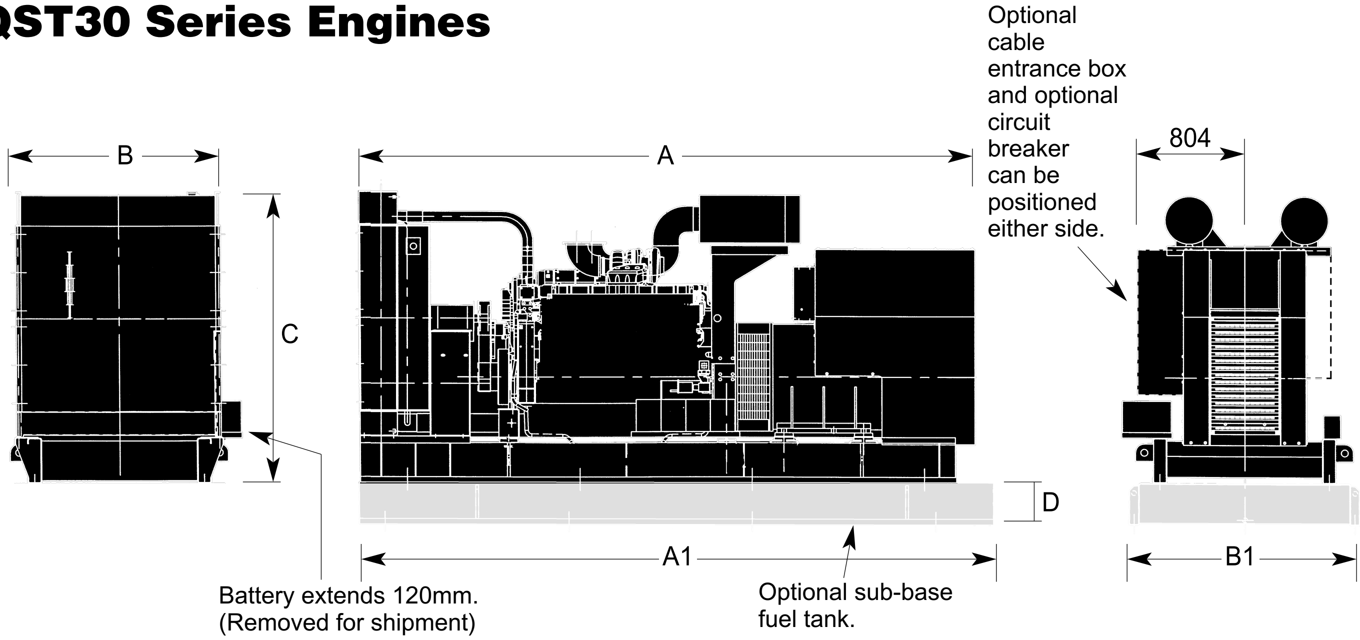
580 kW - 888 kW 50 Hz QST30 Series Engines

Generating Sets – 50 Hz

Set output	380-440 V 50 Hz	380-440 V 50 Hz	380-440 V 50 Hz	380-440 V 50 Hz
Prime at 40°C ambient	580 kWe 725 kVA	640 kWe 800 kVA	751 kWe 939 kVA	800 kWe 1000 kVA
Model (Prime)	580 DFHA	640 DFHB	751 DFHC	800 DFHD
Standby at 40°C ambient	640 kWe 800 kVA	713 kWe 891 kVA	833 kWe 1041 kVA	888 kWe 1110 kVA
Model (Standby)	640 DFHA	713 DFHB	833 DFHC	888 DFHD
Engine Make	Cummins	Cummins	Cummins	Cummins
Model	QST30G1	QST30G2	QST30G3	QST30G4
Cylinders	Twelve	Twelve	Twelve	Twelve
Engine build	Vee	Vee	Vee	Vee
Governor/Class	Electronic/A1	Electronic/A1	Electronic/A1	Electronic/A1
Aspiration and cooling	Turbo Aftercooled	Turbo Aftercooled	Turbo Aftercooled	Turbo Aftercooled
Bore and stroke	140 mm x 165 mm	140 mm x 165 mm	140 mm x 165 mm	140 mm x 165 mm
Compression ratio	14:1	14:1	14:1	14:1
Cubic capacity	30.48 Litres	30.48 Litres	30.48 Litres	30.48 Litres
Starting/Min °C	Unaided/1°C	Unaided/1°C	Unaided/7°C	Unaided/7°C
Battery capacity	254 A/hr	254 A/hr	254 A/hr	254 A/hr
Engine output – Prime	634 kWm	697 kWm	806 kWm	880 kWm
Engine output – Standby	701 kWm	768 kWm	895 kWm	970 kWm
Maximum load acceptance – single step	570 kWe	570 kWe	583 kWe	622 kWe
Speed	1500 rpm	1500 rpm	1500 rpm	1500 rpm
Alternator voltage regulation	±0.5%	±0.5%	±0.5%	±0.5%
Alternator insulation class	H	H	H	H
Single load step to NFPAII0	100%	100%	100%	100%
Fuel consumption (Prime) 100% load	153 l/hr	168 l/hr	184 l/hr	202 l/hr
Fuel consumption (Standby) 100% load	169 l/hr	187 l/hr	204 l/hr	224 l/hr
Lubrication oil capacity	154 Litres	154 Litres	154 Litres	154 Litres
Base fuel tank capacity – open set	1700 Litres	1700 Litres	1700 Litres	1700 Litres
Coolant capacity – radiator and engine (40°C)	169 Litres	169 Litres	169 Litres	302 Litres
Coolant capacity – radiator and engine (50°C)	175 Litres	175 Litres	175 Litres	342 Litres
Exhaust temp – full load prime	527°C	538°C	541°C	565°C
Exhaust gas flow – full load prime	7182 m^3/hr	7977 m^3/hr	8748 m^3/hr	10728 m^3/hr
Exhaust gas back pressure max	76 mm Hg	76 mm Hg	76 mm Hg	51 mm Hg
Air flow – radiator (40°C ambient)*	15.5 m^3/s	15.5 m^3/s	15.5 m^3/s	18 m^3/s
Pusher fan head (duct allowance) 40°C*	13 mm Wg	13 mm Wg	*13 mm Wg	*13 mm Wg
Air intake – engine	2544 m^3/hr	2794 m^3/hr	3114 m^3/hr	3402 m^3/hr
Air flow – radiator (50°C ambient)*	17.6 m^3/s	17.6 m^3/s	18.1 m^3/s	24.8 m^3/s
Pusher fan head (duct allowance) 50°C*	13 mm Wg	13 mm Wg	13 mm Wg	13 mm Wg
Total heat radiated to ambient	126 kW	137 kW	137 kW	152 kW
Engine derating – altitude	4% per 300 m above 1524 m	4% per 300 m above 1524 m	4% per 300 m above 1000 m	5% per 300 m above 1000 m
Engine derating – temperature	2% per 11°C above 40°C (52°C below 305 m)	2% per 11°C above 40°C (52°C below 305 m)	2% per 11°C above 40°C	4% per 5°C above 50°C†

In accordance with ISO 8528, BS5514.
Prime: Continuous running at variable load for unlimited periods with 10% overload available for 1 hour in any 12 hour period.
Standby: Continuous running at variable load for duration of an emergency.
Prime and standby ratings are outputs at 40°C (104°F) ambient temperature.
*Subject to factory verification.
†No temperature derating is applicable to any of these generator sets with a Class H alternator up to 50°C. For Class F alternators refer to factory.

QST30 Series Engines

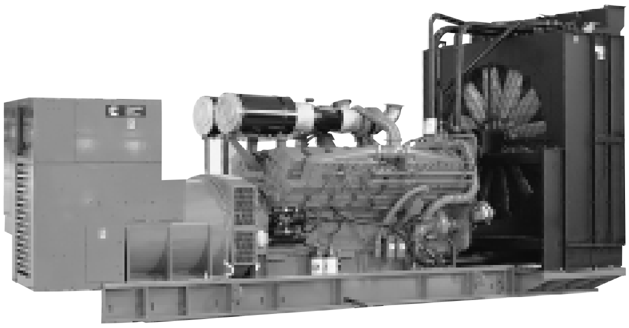


Model	Engine	Dimensions and Weights (mm/kg)						Set Weight kg Dry	Set Weight kg Wet	Tank Weight kg (dry)	Tank Weight kg (wet)
		A	A1	B	B1	C	D				
580 DFHA	CP700-5	4297	4460	1442	1640	2092	300	6552	6850	850	2210
640 DFHB	CP800-5	4297	4460	1442	1640	2092	300	6702	7000	850	2210
751 DFHC	CP900-5	4297	4460	1442	1640	2092	300	7152	7450	850	2210
800 DFHD	CP1000-5	4547	4460	1722	1640	2332	300	7712	8000	850	2210

Set weights are **without** sub-base tank.
Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

Power Generation

1005 kW - 1340 kW 50 Hz
KTA50 Series Engines



Model 1125 DFLE with 50°C radiator fitted.

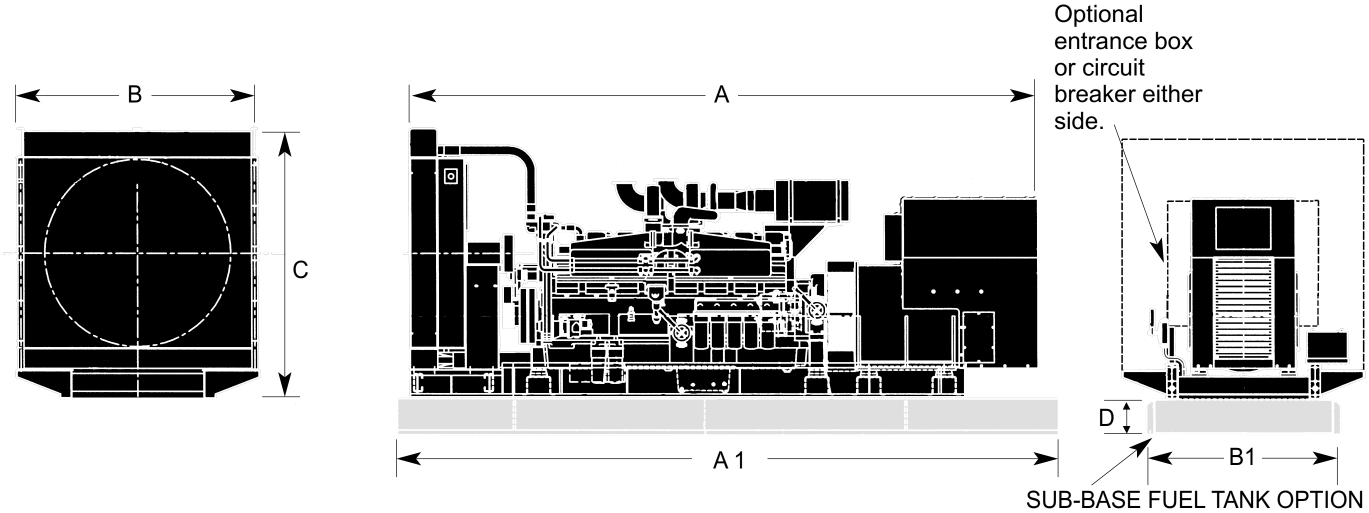
Generating Sets – 50 Hz

Set output	380-440 V 50 Hz	380-440 V 50 Hz
Prime at 40°C ambient	1005 kWe 1256 kVA	1125 kWe 1406 kVA
New Model (Prime)	1005 DFLC	1125 DFLE
Standby at 40°C ambient	1120 kWe 1400 kVA	1340 kWe 1675 kVA
New Model (Standby)	1120 DFLC	1340 DFLE
Engine Make	Cummins	Cummins
Model	KTA50G3	KTA50G8
Cylinders	Sixteen	Sixteen
Engine build	60° Vee	Vee
Governor / Class	Electronic / A1	Electronic / A1
Aspiration and cooling	Turbo Aftercooled	Turbo Aftercooled
Bore and stroke	159 mm x 159 mm	159 mm x 159 mm
Compression ratio	13.9:1	14.9:1
Cubic capacity	50.3 Litres	50.3 Litres
Starting / Min °C	Unaided / 7°C	Unaided / 7°C
Battery capacity	254 A/hr	254 A/hr
Nett Engine output – Prime	1076 kWm	1168 kWm
Nett at flywheel – Standby	1206 kWm	1397 kWm
Maximum load acceptance – single step (cold)	640 kWe	900 kWe
Speed	1500 rpm	1500 rpm
Alternator voltage regulation	±0.5%	±0.5%
Alternator insulation class	H	H
Single load step to NFPA 110	100%	100%
Fuel consumption (Prime) 100% load	254 l/hr	289 l/hr
Fuel consumption (Standby) 100% load	282 l/hr	345 l/hr
Lubrication oil capacity	177 Litres	204 Litres
Base fuel tank capacity – open set	2000 Litres	2000 Litres
Coolant capacity – radiator and engine	351 Litres	400 Litres
Exhaust temp – full load prime	518°C	482°C
Exhaust gas flow – full load prime	13590 m^3/hr	13842 m^3/hr
Exhaust gas back pressure max (standby)	51 mm Hg	51 mm Hg
Air flow – radiator (40°C ambient)†	21.6 m^3/s	21.7 m^3/s
Pusher fan head (duct allowance) 40°C†	13 mm Wg	13 mm Wg
Air intake – engine (prime)	5166 m^3/hr	5400 m^3/hr
Air flow – radiator (50°C ambient)†	27.1 m^3/s	28.4 m^3/s
Pusher fan head (duct allowance) 50°C†	13 mm Wg	15 mm Wg
Total heat radiated to ambient	176 kW	210 kW
Engine derating – altitude	Refer to derate curves	Refer to derate curves
Engine derating – temperature	Refer to derate curves	Refer to derate curves

In accordance with ISO 8528, ISO 3046.
Prime: Continuous running at variable load for unlimited periods with 10% overload available for 1 hour in any 12 hour period.
Standby: Continuous running at variable load for duration of an emergency.
†Subject to factory verification.

For TA-LUFT engine parameters refer to factory.

KTA50 Series Engines



Model	Engine	Dimensions and Weights (mm/kg)						Set Weight	Set Weight	Tank Weight	Tank Weight
		A	A1	B1	B	C	D	kg Dry	kg Wet	kg (wet)	kg (dry)
DFLC	KTA50G3	5290	5690	1640	2000	2238	300	9743	10300	2755	1075
DFLG	KTA50G6	5290	5690	1640	2000	2238	300	9743	10300	2755	1075
DFLH	KTA50G7	5455	5690	1640	2033	2241	300	9943	10646	2755	1075
DFLE	KTA50G8	5866	5690	1640	2033	2333	300	11140	11700	2755	1075
DFLE	*KTA50G8	5880	5690	1640	2033	2771	300	11540	12100	2755	1075

*With 50°C ambient radiator

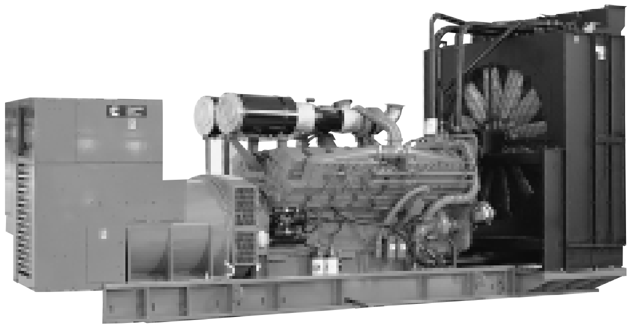
Floor mounted circuit breaker and load terminal cubicle (for use above 2000 amps)			
Capacity amps	Width mm	Depth mm	Height mm
1600	1000	1050	1500
2000	1000	1050	1500
2500	1000	1050	1500
3200	1000	1050	1500
4000	Refer to Factory		

Set weights are **without** sub-base tank.
Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

Technical Data

Power Generation

1200 kW - 1340 kW 50 Hz KTA50GS8 Series Engine



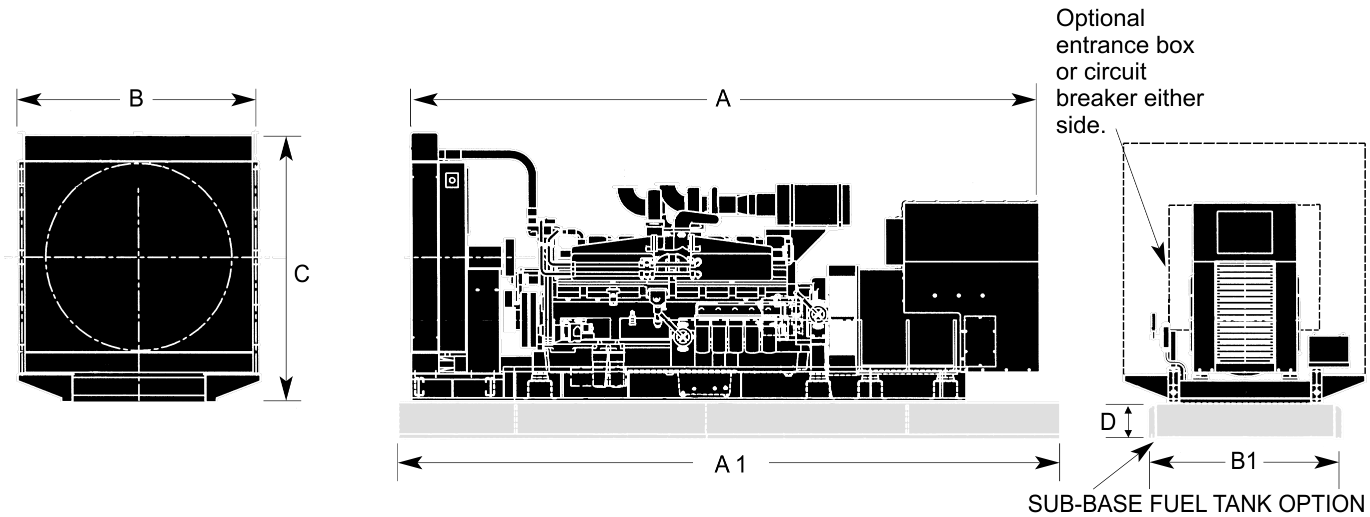
Generating Sets – 50 Hz

Typical Model with 50°C radiator fitted.

Set output	380-440 V 50 Hz
Prime at 50°C ambient	1200 kWe 1500 kVA
Model (Prime)	1200 DFLF
Standby at 50°C ambient	1340 kWe 1675 kVA
Model (Standby)	1340 DFLF
Engine Make	Cummins
Model	KTA50GS8
Cylinders	Sixteen
Engine build	60° Vee
Governor / Class	Electronic / A1
Aspiration and cooling	Turbo Aftercooled
Bore and stroke	159 mm x 159 mm
Compression ratio	14.9:1
Cubic capacity	50.3 Litres
Starting / Min °C	Unaided / 7°C
Battery capacity	254 A/hr
Nett Engine output – Prime	1287 kWm
Nett Engine output – Standby	1429 kWm
Maximum load acceptance – single step (cold)	744 kWe
Speed	1500 rpm
Alternator voltage regulation	±0.5%
Alternator insulation class	H
Single load step to NFPAIIO	100%
Fuel consumption (Prime) 100% load	309 l/hr
Fuel consumption (Standby) 100% load	345 l/hr
Lubrication oil capacity	204 Litres
Base fuel tank capacity – open set	2000 Litres
Coolant capacity – radiator and engine	315 Litres
Exhaust temp – full load prime	490°C
Exhaust gas flow – full load prime	14490 m^3/hr
Exhaust gas back pressure max (standby)	51 mm Hg
Air flow – radiator (40°C ambient)†	21.7 m^3/s
Pusher fan head (duct allowance) 40°C†	13 mm Wg
Air intake – engine (prime)	5600 m^3/hr
Air flow – radiator (50°C ambient)†	28.4 m^3/s
Pusher fan head (duct allowance) 50°C†	12 mm Wg
Total heat radiated to ambient	254 kW

In accordance with BS5514 and ISO3046.
Prime: Continuous running at variable loads for an unlimited time with a 10% overload capability for 1 hour in every 12. Alternator in accordance with ISO8528-3.
Standby: Continuous running at variable load for duration of an emergency.
†Subject to factory verification.

KTA50GS8 Series Engine



2000 Model	Engine	Dimensions and Weights (mm/kg)						Set Weight kg Dry	Set Weight kg Wet	Tank Weight kg (wet)	Tank Weight kg (dry)
		A	A1	B1	B	C	D				
DFLF	KTA50GS8	5866	5690	1640	1785	2241	300	9743	10300	2755	1075

Floor mounted circuit breaker and load terminal cubicle (for use above 2000 amps)			
Capacity amps	Width mm	Depth mm	Height mm
1600	1000	1050	1500
2000	1000	1050	1500
2500	1000	1050	1500
3200	1000	1050	1500
4000	Refer to Factory		

Set weights are **without** sub-base tank.
Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

1500 kW - 1760 kW 50 Hz QSK60 Series Engines

Generating Sets – 50 Hz

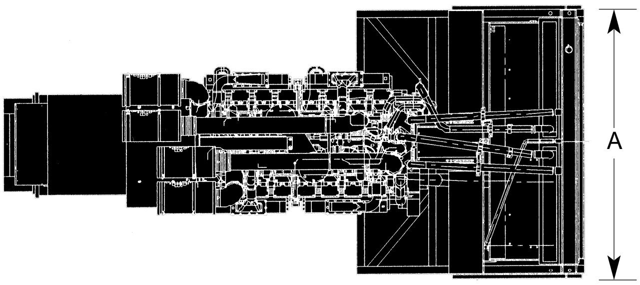
	Standby	Prime	Standby	Prime
Ratings kW (kVA)	1650 (2063)	1500 (1875)	1760 (2200)	1600 (2000)
Model	1650 DQKC	1500 DQKC	1760 DQKD	1600 DQKD
Engine Model	QSK60G3	QSK60G3	QSK60G4	QSK60G4
Aspiration	Turbocharged and Aftercooled	Turbocharged and Aftercooled	Turbocharged and Aftercooled	Turbocharged and Aftercooled
Gross Engine Power Output	1,790 kWm	1,615 kWm	1,915 kWm	1,730 kWm
BMEP	2,389 kPa	2,159 kPa	2,544 kPa	2,299 kPa
Bore	159 mm	159 mm	159 mm	159 mm
Stroke	190 mm	190 mm	190 mm	190 mm
Piston Speed	9.5 m/s	9.5 m/s	9.5 m/s	9.5 m/s
Compression Ratio	14.5:1	14.5:1	14.5:1	14.5:1
Lube Oil Capacity	280 Litres	406 Litres	280 Litres	398 Litres
Overspeed Limit	1,850 ± 50 rpm	1,850 ± 50 rpm	1,850 ± 50 rpm	1,850 ± 50 rpm
Fuel Consumption Load	1/4 1/2 3/4 Full	1/4 1/2 3/4 Full	1/4 1/2 3/4 Full	1/4 1/2 3/4 Full
Fuel Consumption L/hr	119 202 293 393	111 187 266 356	125 220 325 427	114 200 291 394
Maximum Fuel Inlet Restriction	8.4 kPa (63 mm Hg)	8.4 kPa (63 mm Hg)	13.5 kPa (101 mm Hg)	13.5 kPa (101 mm Hg)
Maximum Fuel Return Restriction	30.4 kPa (228 mm Hg)	30.4 kPa (228 mm Hg)	30.5 kPa (229 mm Hg)	30.5 kPa (229 mm Hg)
Maximum Fuel Inlet Temperature	70°C	70°C	70°C	70°C
Maximum Fuel Return Temperature	71°C	71°C	71°C	71°C
Coolant Capacity (with radiator)	410 Litres	410 Litres	621 Litres	621 Litres
Coolant Flow Rate (engine jacket)	1438 L/Min	1438 L/Min	1438 L/Min	1438 L/Min
Coolant Flow Rate (aftercooler)	413 L/Min	413 L/Min	413 L/Min	413 L/Min
Heat Rejection to Eng Jacket Coolant	460 kW	420 kW	500 kW	450 kW
Heat Rejection to Exhaust	1195 kWm	1050 kWm	1325 kWm	1180 kWm
Heat Rejection to Aftercooler Coolant	405 kWm	355 kWm	455 kWm	400 kWm
Heat Rejection to Fuel	35 kWm	35 kWm	35 kWm	35 kWm
Heat Radiated to Ambient	160 kWm	145 kWm	175 kWm	160 kWm
Max Coolant Friction Head (JW)	69 kPa	69 kPa	69 kPa	69 kPa
Max Coolant Friction Head (aftercooler)	35 kPa	35 kPa	35 kPa	35 kPa
Maximum Coolant Static Head	18.3 m	18.3 m	18.3 m	18.3 m
Heat Ex. Max Raw Water Flow (JW/AC)	1,363 L/Min	1,363 L/Min	1,363 L/Min	1,363 L/Min
Heat Ex. Max Raw Water Press (JW/AC/Fuel)	1,034 kPa	1,034 kPa	1,034 kPa	1,034 kPa
Heat Ex. Max Raw Water Flow (Fuel)	144 L/Min	144 L/Min	144 L/Min	144 L/Min
Max Top Tank Temp (engine jacket)	104°C	100°C	104°C	100°C
Max Inlet Temp (aftercooler)	65°C	65°C	65°C	65°C
Combustion Air	139 m^3/min	125 m^3/min	144 m^3/min	136 m^3/min
Maximum Air Cleaner Restriction	6.2 kPa	6.2 kPa	6.2 kPa	6.2 kPa
Alternator Cooling Air	250 m^3/min	250 m^3/min	246 m^3/min	246 m^3/min
Radiator Cooling Air	1584 m^3/min	1584 m^3/min	1869 m^3/min	1869 m^3/min
Max Static Restriction	125 Pa	125 Pa	125 Pa	125 Pa
Exhaust Gas Flow (Full Load)	334 m^3/min	303 m^3/min	337 m^3/min	311 m^3/min
Exhaust Gas Temperature	515°C	505°C	450°C	430°C
Maximum Back Pressure	6.7 kPa	6.7 kPa	6.7 kPa	6.7 kPa

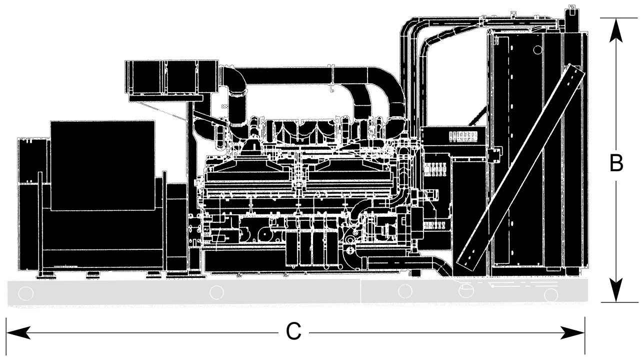
RTF – Refer to factory.

Data subject to factory verification.

For TAL model data refer to factory.

QSK60 Series Engines





Model	Dim "A"	Dim B	Dim C	Dry Weight*
1500 DQKC	2286 mm	2612 mm	6090 mm	15188 kg
1600 DQKD	2286 mm	2612 mm	6090 mm	16644 kg
1650 DQKC	2286 mm	2612 mm	6090 mm	15188 kg
1760 DQKD	2286 mm	2612 mm	6090 mm	16649 kg

Floor mounted circuit breaker and load terminal cubicle (for use above 2000 amps)			
Capacity amps	Width mm	Depth mm	Height mm
1600	1000	1050	1500
2000	1000	1050	1500
2500	1000	1050	1500
3200	1000	1050	1500
4000	Refer to Factory		

*Weight given is with standard low voltage alternator. Genset is shipped filled with engine oil and coolant.
Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

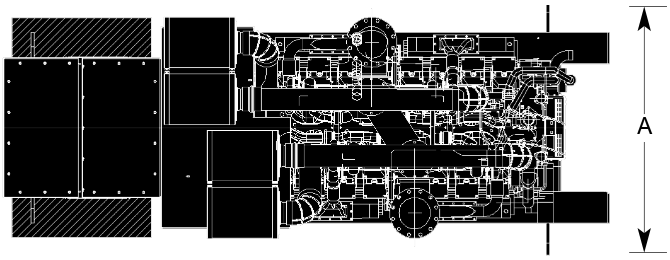
1500 kW - 1760 kW 50 Hz
QSK60 TA-Luft Series

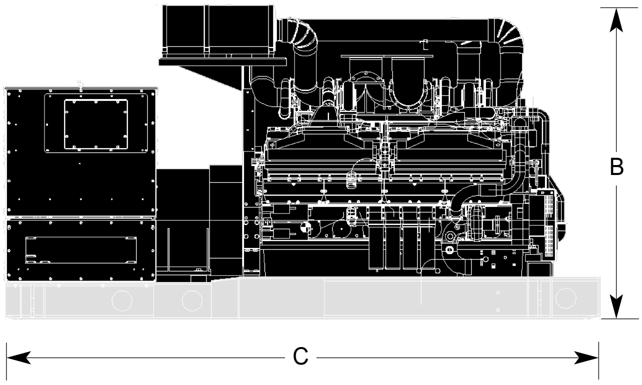
Generating Sets – 50 Hz

	QSK60 G3 TA Luft				QSK60 G3 TA Luft				QSK60 GS3 TA Luft				QSK60 GS3 TA Luft			
	Standby				Prime				Standby				Prime			
Ratings kW (kVA)	1650 (2063) note 1				1500 (1875) note 1				1760 (2200) note 1				1600 (2000) note 1			
Model	1650 DQKE				1500 DQKE				1760 DQKF				1600 DQKF			
Engine Model	QSK60 G3				QSK60 G3				QSK60 GS3				QSK60 GS3			
Aspiration	Turbocharged and Aftercooled				Turbocharged and Aftercooled				Turbocharged and Aftercooled				Turbocharged and Aftercooled			
Gross Engine Power Output	1,740 kWm				1,565 kWm				1,835 kWm				1,650 kWm			
BMEP	2,305 kPa				2,072 kPa				2,429 kPa				2,185 kPa			
Bore	159 mm				159 mm				159 mm				159 mm			
Stroke	190 mm				190 mm				190 mm				190 mm			
Piston Speed	9.5 m/s				9.5 m/s				9.5 m/s				9.5 m/s			
Compression Ratio	14.5:1				14.5:1				14.5:1				14.5:1			
Lube Oil Capacity	378 Litres				378 Litres				378 Litres				378 Litres			
Engine Speed	1500 rpm				1500 rpm				1500 rpm				1500 rpm			
Overspeed Limit	1,850 ± 50 rpm				1,850 ± 50 rpm				1,850 ± 50 rpm				1,850 ± 50 rpm			
Fuel Consumption Load	1/4	1/2	3/4	Full	1/4	1/2	3/4	Full	1/4	1/2	3/4	Full	1/4	1/2	3/4	Full
Fuel Consumption L/hr	124	226	338	447	115	206	304	399	129	238	355	476	119	216	321	421
Maximum Fuel Flow	1170 L/hr				1170 L/hr				1170 L/hr				1170 L/hr			
Maximum Inlet Restriction	120 mm Hg				120 mm Hg				120 mm Hg				120 mm Hg			
Maximum Fuel Return Restriction	229 mm Hg				229 mm Hg				229 mm Hg				229 mm Hg			
Maximum Fuel Inlet Temperature	70°C				70°C				70°C				70°C			
Maximum Fuel Return Temperature	113°C				113°C				113°C				113°C			
Fan Load (Remote Fan)	17.6 kW				17.6 kW				17.6 kW				17.6 kW			
Coolant Capacity (with radiator)	459 Litres				459 Litres				459 Litres				459 Litres			
Coolant Flow Rate (engine jacket)	1438 L/Min				1438 L/Min				1438 L/Min				1438 L/Min			
Coolant Flow Rate (aftercooler)	426 L/Min				426 L/Min				426 L/Min				426 L/Min			
Heat Rejection to Eng Jacket Coolant	530 kW				490 kW				548 kW				509 kW			
Heat Rejection to Aftercooler Coolant	534 kWm				482 kWm				545 kWm				520 kWm			
Heat Rejection to Fuel	22 kWm				22 kWm				22 kWm				22 kWm			
Heat Radiated to Room	175 kWm				157 kWm				187 kWm				165 kWm			
Max Coolant Friction Head (JW)	69 kPa				69 kPa				69 kPa				69 kPa			
Max Coolant Friction Head (aftercooler)	35 kPa				35 kPa				35 kPa				35 kPa			
Maximum Coolant Static Head	18.3 m				18.3 m				18.3 m				18.3 m			
Heat Ex. Max Raw Water Flow (JW/AC)	1,363 L/Min				1,363 L/Min				1,363 L/Min				1,363 L/Min			
Heat Ex. Max Raw Water Press (JW/AC/Fuel)	1,034 kPa				1,034 kPa				1,034 kPa				1,034 kPa			
Heat Ex. Max Raw Water Flow (Fuel)	144 L/Min				144 L/Min				144 L/Min				144 L/Min			
Max Top Tank Temp (engine jacket)	104°C				100°C				104°C				100°C			
Max Inlet Temp (aftercooler) note 3	40°C				40°C				40°C				40°C			
Combustion Air	139 m³/min				125 m³/min				139 m³/min				125 m³/min			
Maximum Air Cleaner Restriction	6.2 kPa				6.2 kPa				6.2 kPa				6.2 kPa			
Alternator Cooling Air	246 m³/min				246 m³/min				246 m³/min				246 m³/min			
Radiator Cooling Air	-				-				-				-			
Max Static Restriction	125 Pa				125 Pa				125 Pa				125 Pa			
Exhaust Gas Flow (Full Load)	360 m³/min				334 m³/min				376 m³/min				346 m³/min			
Exhaust Gas Temperature	457°C				440°C				471°C				448°C			
Maximum Back Pressure	6.8 kPa				6.8 kPa				6.8 kPa				6.8 kPa			
Altitude Derating Factors - Engine	1400 m - note 2				1400 m - note 2				900 m - note 2				900 m - note 2			
Temperature Derating Factor - Engine	40°C - note 2				40°C - note 2				40°C - note 2				40°C - note 2			

RTF – Refer to factory.
Data subject to factory verification.
note 1. Ratings without cooling fan.
note 2. Consult factory for assistance with derate.
note 3. For low emissions performance in standard reference conditions.

QSK60 TA-Luft Series





Model	Dim 'A'	Dim 'B'	Dim 'C'	Dry Weight*
1500 DQKE	2068 mm	2515 mm	4894 mm	12800 kg
1600 DQKF	2068 mm	2515 mm	4894 mm	14611 kg
1650 DQKE	2068 mm	2515 mm	4894 mm	12800 kg
1760 DQKF	2068 mm	2515 mm	4894 mm	14611 kg

Floor mounted circuit breaker and load terminal cubicle (for use above 2000 amps)			
Capacity amps	Width mm	Depth mm	Height mm
1600	1000	1050	1500
2000	1000	1050	1500
2500	1000	1050	1500
3200	1000	1050	1500
4000	Refer to Factory		

*Weight given is with standard low voltage alternator. Genset is shipped filled with engine oil and coolant.
Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

Note: Generators for sites where TA Luft is required have remote mounted cooling systems.

Power Generation

Gas Power Generation

315 kWe 50 Hz
QSK19G Series Engines

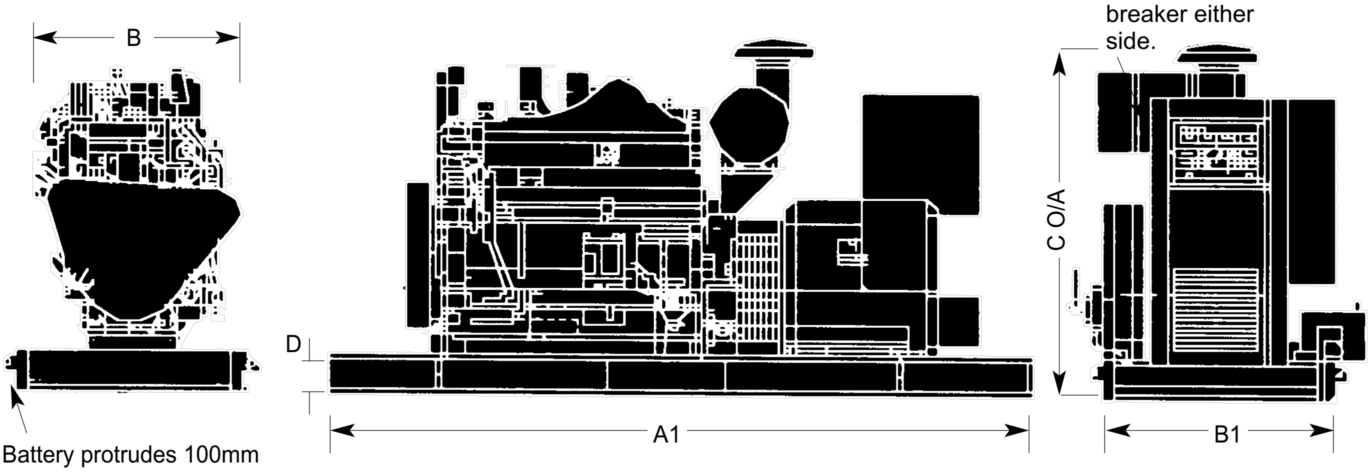
Generating Sets – 50 Hz

Genset Data	50 Hz
Model	315 GFBA
Continuous Duty Set Output	315/394 kWe/kVA @ 0.8pf
Alternator voltage regulation	+/-1%
Alternator insulation class	IP22
Alternator insulation/temp rise	H/H
Battery Capacity	190 Ah
Engine Data	
Engine Model	QSK 19G
Bore	159 mm
Stroke	159 mm
Capacity	19 Litres
Cylinder Configuration	6 in line
Aspiration	Turbocharged and Aftercooled
RPM	1500
Compression Ratio	11:1
Brake Mean Effective Pressure	14.0 bar (G)
Effective mechanical output with engine driven pumps	330 kWm

Ratings in accordance with ISO 8528, BS5514 at a maximum ambient temperature of 35°C and a methane number above 75.No overload available. For detailed technical data refer to the specific data sheet.

Gas Power Generation

QSK19G Series Engines



	Dimensions and Weights (mm)			Set Weight	Set Weight
	A	B	C	kg Dry	kg Wet
Without bed mounted radiator	3490	1266	1792	3856	3990

Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application. Specifications may change without notice.

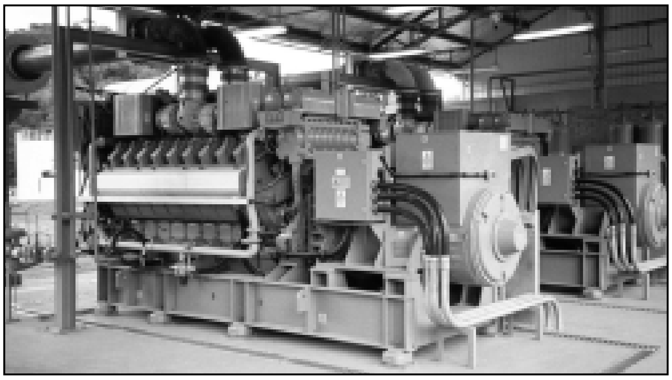
Gas Power Generation

1370-1570 kWe 50 Hz
QSV81G Series Engines

	Units	50 Hz	50 Hz
Generator Set Data			
Model		1370 GQMA	1570 GQMB
Generator electrical output	kWe	1370	1570
Alternator voltage regulation		+/-1%	+/-1%
Alternator protection class		IP22	IP22
Alternator insulation/temperature rise		H/H	H/H
Starting air bottle recommended pressure	bar (G)	30-40	30-40
Electric starter voltage	V	24	24
Minimum battery capacity @ 20°C	Ah	720	720
Engine Data			
Engine Model		QSV81-G	QSV81-G
Bore	mm	180	180
Stroke	mm	200	200
Capacity	litres	81.44	81.44
Configuration		16 V	16 V
Aspiration		TCA	TCA
Engine speed	rpm	1500	1500
BMEP	bar (G)	14	16
Effective mechanical output with engine driven pumps	kW	1425	1629

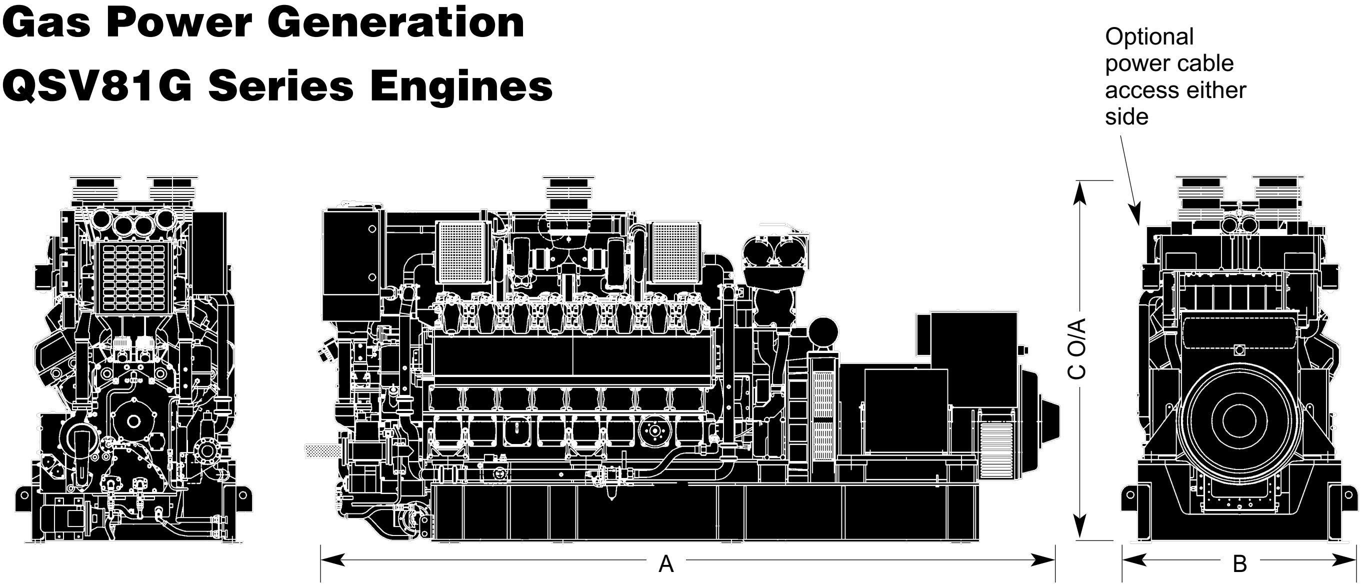
COP rating in accordance with ISO 8528 and BS5514 at a maximum aspiration air temperature of 35°C, a maximum altitude of 1000 metres above sea level and with the generator sets operating in parallel with the utility. No overload available.

For detailed technical data on the various engine versions available refer to the specific data sheet.



Cummins Power Generation

Gas Power Generation
QSV81G Series Engines



	Dimensions and Weights (mm)			Set Weight	Set Weight
	A	B	C	kg Dry	kg Wet
1370 GQMA Without bed mounted radiator	5356	1721	2661	14832	16137
1570 GQMA Without bed mounted radiator	5356	1721	2661	15300	16637

Floor mounted circuit breaker and load terminal cubicle (for use above 2000 amps)			
Capacity amps	Width mm	Depth mm	Height mm
1600	1000	1050	1500
2000	1000	1050	1500
2500	1000	1050	1500
3200	1000	1050	1500
4000	Refer to Factory		

Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

Power Generation

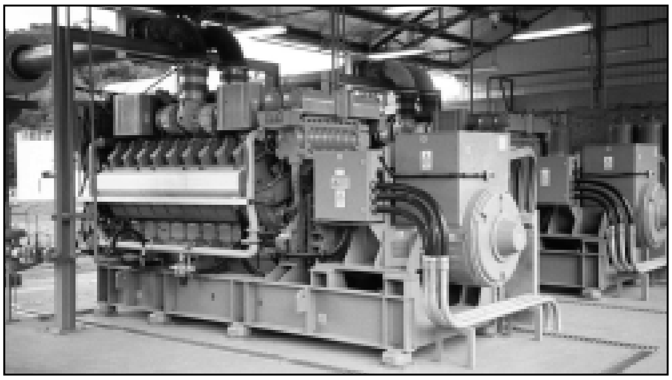
Gas Power Generation

1540-1750 kWe 50 Hz
QSV91G Series Engines

	Units	50 Hz	50 Hz
Generator Set Data			
Model		1540 GQNA	1750 GQNB-50
Generator electrical output	kWe	1540	1750
Alternator voltage regulation		+/-1%	+/-1%
Alternator protection class		IP22	IP23
Alternator insulation/temperature rise		H/H	H/H
Starting air bottle recommended pressure	bar (G)	30-40	30-40
Electric starter voltage	V	24	24
Minimum battery capacity @ 20°C	Ah	720	720
Engine Data			
Engine Model		QSV91-G	QSV91-G
Bore	mm	180	180
Stroke	mm	200	200
Capacity	litres	91.62	91.62
Configuration		18 V	18 V
Aspiration		TCA	TCA
Engine speed	rpm	1500	1500
BMEP	bar (G)	14	16
Effective mechanical output with engine driven pumps	kW	1600	1832

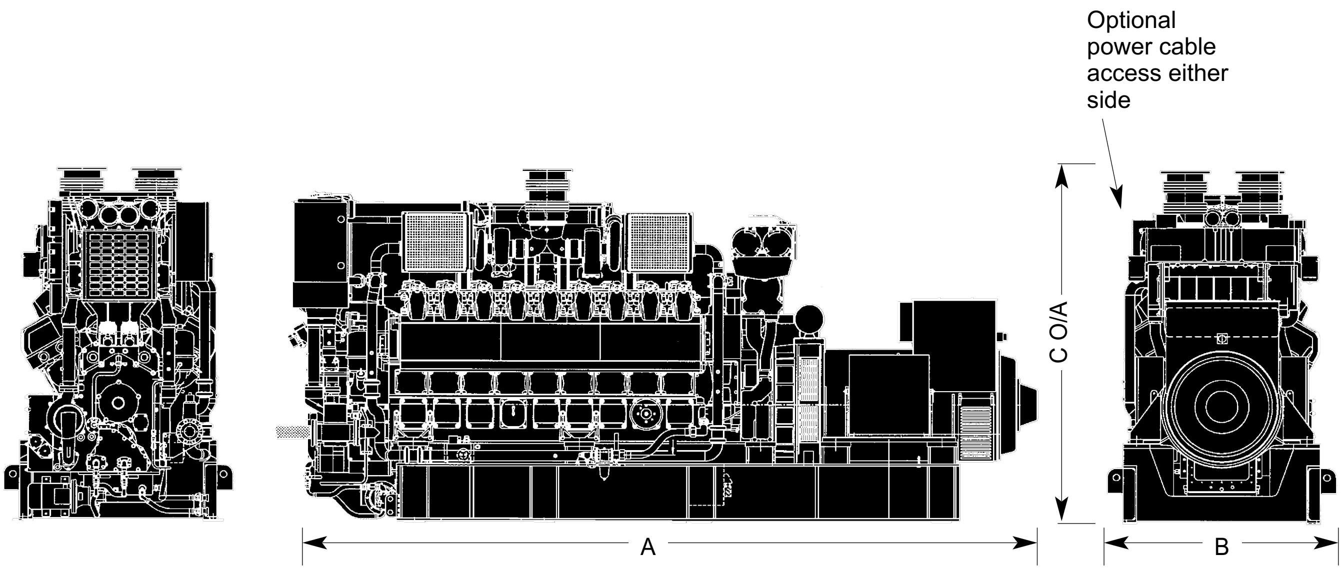
COP rating in accordance with ISO 8528 and BS5514 at a maximum aspiration air temperature of 35°C, a maximum altitude of 1000 metres above sea level and with the generator sets operating in parallel with the utility. No overload available.

For detailed technical data on the various engine versions available refer to the specific data sheet.



Power Generation

Gas Power Generation
QSV91G Series Engines



	Dimensions and Weights (mm)			Set Weight	Set Weight
	A	B	C	kg Dry	kg Wet
1540 GQNA Without bed mounted radiator	5606	1721	2661	16062	17507
1750 GQNB-50 Without bed mounted radiator	5606	1721	2661	16562	18000

Floor mounted circuit breaker and load terminal cubicle (for use above 2000 amps)			
Capacity amps	Width mm	Depth mm	Height mm
1600	1000	1050	1500
2000	1000	1050	1500
2500	1000	1050	1500
3200	1000	1050	1500
4000	Refer to Factory		

Dimensions and weights are for **guidance** only. Do not use for installation design. Ask for certified drawings on your specific application.
Specifications may change without notice.

60 Hz Ratings* Diesel Powered Generating Sets

Prime Rating			Engine Model	Standby Rating		
KVA	KW	Prime Model		KVA	KW	Standby Model
40	32	32 DGGC	B3.3G1	43	35	35 DGGC
57	46	46 DGHC	B3.3G2	63	52	52 DGHC
44	36	36 DGBC	4B3.9G	50	40	40 DGBC
60	48	48 DGCG	4BT3.9G4	64	51	51 DGCG
73	59	59 DGCH	4BT3.9G4	81	65	65 DGCH
83	66	66 DGCC	4BTA3.9G2	89	72	72 DGCC
95	76	76 DGDH	6BT5.9G6	106	85	85 DGDH
119	95	95 DGDJ	6BT5.9G6	131	105	105 DGDJ
153	122	122 DGEA	6CT8.3G2	167	133	133 DGEA
210	168	168 DGFB	6CTA8.3G2	228	182	182 DGFB
NA	NA	NA	LTA10G2	250	200	200 DFAA
254	203	203 DFAB	LTA10G2	NA	NA	NA
286	229	229 DFAC	LTA10G1	315	252	252 DFAC
351	281	281 DFCB	NTA855G2	390	312	312 DFCB
402	322	322 DFCC	NTA855G3	437	350	350 DFCC
513	410	410 DFEJ	QSX15G9	563	450	450 DFEJ
569	455	455 DFEK	QSX15G9	625	500	500 DFEK
439	351	351 DFEB	KTA19G2	500	400	400 DFEB
504	403	403 DFEL	KTA19G3	562	450	450 DFEL
561	449	449 DFED	KTA19G4	626	501	501 DFED
681	545	545 DFGB	VTA28G5	754	603	603 DFGB
862	690	690 DFHA	QST30G1	950	760	760 DFHA
920	736	736 DFHB	QST30G2	1012	810	810 DFHB
1044	835	835 DFHC	QST30G3	1156	925	925 DFHC
1160	928	928 DFJD	KTA38G4	1276	1020	1020 DFJD
1400	1120	1120 DFLC	KTA50G3	1587	1270	1270 DFLC
1608	1286	1286 DFLE	KTA50G9	1931	1545	1545 DFLE
2250	1800	1800 DQKC	QSK60G6	2500	2000	2000 DQKC

Rating Conditions:

60 Hz ratings at 40°C (104°F) ambient temperature with a 50°C (122°F) radiator.

Ratings: Prime (Unlimited Running Time), applicable for supplying power in lieu of commercially-purchased power.

Prime power is available at a variable load for an unlimited number of hours. A 10% overload capacity is available. Nominally rated. In accordance with ISO 8528, ISO 3046, AS 2789, DIN 6271 and BS 5514.

Standby: Applicable for supplying emergency power for the duration of normal power interruption. No sustained overload capability is available for this rating. Nominally rated. In accordance with ISO 3046, AS 2789, DIN 6271 and BS 5514.

***60 Hz Ratings** – see separate 60 Hz edition for Technical Data Information and Recommended Room Sizes.

5 MW or 10 MW Power Modules

Modules of 5 MW or 10 MW in Packaged Power Stations.

Cummins Power Generation have introduced a unique concept for the creation of Power Stations by extending, in 5 MW increments, a design that enables power stations to be constructed on site up to 60 MW very quickly. Using generating sets in containerised form, on a fast track delivery, the plan enables the user to have a complete working Power Station installed with the minimum effort.

A complete Power Station, for example of 10 MW can be installed and on line within approx 10 days from the equipments arrival at the site.

All plant and equipment are self contained in 20 ft (6m) containers. As an example a 10 MW module would consist of 33 x 20 ft (6m) containers comprising 14 x 1 MW diesel generator sets, 10 space frame containers each with 22000 litre fuel tanks, 6 containers with 14 x 1 MW low to high voltage transformers, 2 air conditioned containers with medium voltage switchboards linked to distribution equipment and an air conditioned container for the control room.

The system has the capability of supplying power to either 50 Hz, 11 kV or switching to 60 Hz 13.8 kV without any modification, in up to 55°C ambient temperatures.

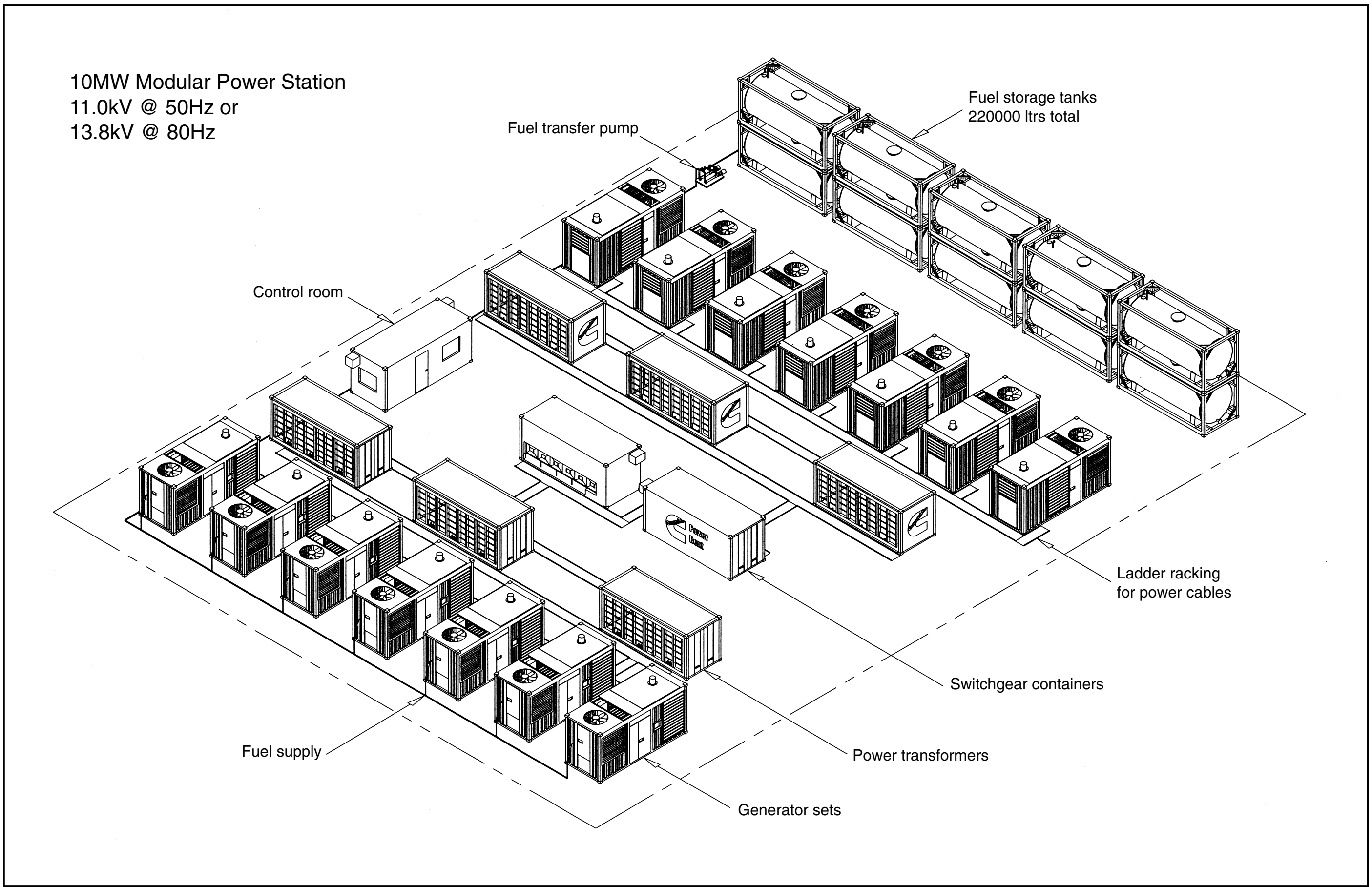
All interconnection power and control cables, cut to length, terminated and colour coded, are provided plus all the fuel lines pre-cut and unionised. These pre-designed and factory-made cables and fuel lines ensure that time spent on site is drastically reduced, ensuring accurate and correct positioning, bringing the Modular Power Station on line very quickly. The system is designed for ease of installation, without the need for skilled labour.

All containers are conventional CSC rated and certified, suitable for stacking and ease of transportation by road, rail, sea or air.

Example Product Specification for 10 MW Power Station

Equipment comprises of:

- 14 No. Containerised Diesel generator sets each rated 1031 kW 1289 kVA @ 50 Hz or 1135 kW 1418 kVA @ 60 Hz prime power.
- 14 No. Containerised Power step up transformers.
- 1 No. Containerised Neutral earthing transformer.
- 2 No. Containerised Switchrooms.
- 1 No. Containerised control room.
- 10 No. Containerised diesel fuel tanks (optional).



Pictorial representation of a 10 MW Power Station.

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5 MW or 10 MW Power Modules

Power Generation

Project Specification for 10 MW Power Station Equipment

General

All equipment offered is suitable for operation at 50 Hz, 400/11,000 V and 60 Hz, 480/13,800 V, at an ambient of up to 55°C.

Power is generated at 400/480 V, 50/60 Hz and stepped up to 11,000/13,800 V by individual transformers.

This is fed via dedicated circuit breakers to a switchgear line up.

Each switchroom has an interconnector, allowing power coupling between switchrooms when used as a 10 MW station.

Each switchroom also has its own outgoing feeder, and in the case of a 10 MW requirement, it is possible to take the station load from one or other outgoing feeder, or both.

A Neutral earthing transformer is offered for island mode application.

The station is managed from a purpose designed control room.

Cylindrical ISO fuel tanks are supplied when required. This provides for approx 6 days operation at full load.

Low and medium voltage power cables and control signal cables are cut to length and pre-terminated for easy connection on site.

Diesel fuel lines are pre-cut and unionised and supplied with all necessary fittings for easy connection on site.

The system includes a fuel transfer pump.

Diesel Generator

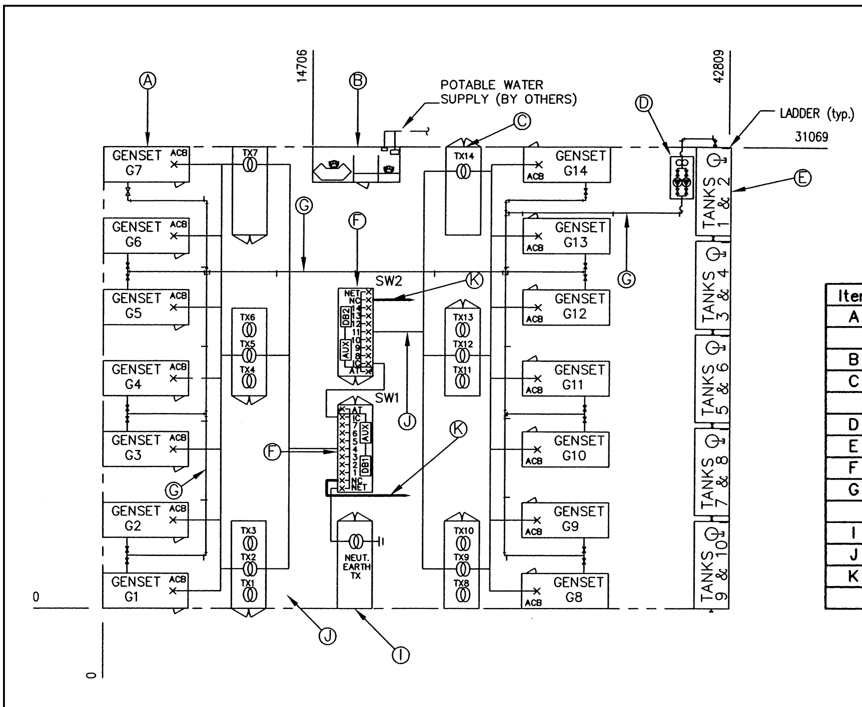
The diesel generator is rated 1031 kWe, 1250 kVA prime, 843 kWe, 1054 kVA 50 Hz continuous and uses the Cummins KTA 50 G3 engine coupled to a brushless alternator.

The set is mounted in a 20 foot, standard ISO, CSC plated, 85 dB(A) at 1m acoustic enclosure.

Features include day tank, radiator, centinnel oil burn device and PowerCommand Control Paralleling.

Sets are suitable for operation in both island mode or in parallel with the public utility and can be configured for base load or load share modes.

Site Power						
Recommended Configurations						
	5MW	10MW	15MW	20MW	30MW	40MW
Equipment						
(a) Number of 1MW sets	7	14	21	28	42	56
(b) Number of 22000 litre tanks	6	10	16	20	30	40
(c) Number of 11-13.8 kV transformers	7	14	21	28	42	56
(d) Number of switchgear containers	1	2	3	4	6	8
(e) Number of control containers	1	1	1	2	2	3
(f) Square Metres of area required per site	35 x 40	40 x 50	50 x 60	60 x 80	80 x 80	100 x 100



Item	Desciption	Details	Qty.
A	GENSETS	1250 kVA, 400 V, 50 Hz	14
		1400 kVA, 480 V, 60 Hz	
B	CONTROL ROOM		1
C	POWER TRANSFORMERS	1250 kVA, 400 V/11.0 kV, 50 Hz	14
		1400 kVA, 480 V/13.8 kV, 60 Hz	
D	PUMPING STATION	FUEL FEED	1
E	FUEL STORAGE TANKS	220000 LTR. APPROX. (TOTAL)	10
F	SWITCH ROOM		2
G	FUEL SUPPLY	ø50	
I	NEUTRAL EARTH TX.	ISLAND MODE ONLY	1
J	POWER CABLE		
K	MAIN OUTGOING FEEDER	11.0 kV @ 50 Hz	1/2
		12.8 kV @ 60 Hz	

Diagrammatic representation of a 10 MW Power Station showing route of fuel lines and cabling.

Power Step Up Transformers

The transformers are of the oil filled ONAN design, suitable to accept 400/480 V at 50/60 Hz and step up to 11,000/13,800 V.

The units are designed to operate at up to 55°C ambient.

Three transformers are fitted into one caged, curtain sided 20ft (6m) ISO container. The curtains need to be rolled up during operation to allow natural cooling of the transformers.

Demountable sides allow for easy removal of transformers in the event of breakdown.

The neutral earthing transformer is fitted in a similar caged container.

Each container is fitted with internal lighting and a 13 A socket.

Switchgear

Each 5 MW power station is served by a switchgear line up mounted in a 20ft (6m) container.

The line up comprises of 7 No. generator incomer breakers, 1 No. switchroom interconnector, 1 No. auxiliary transformer breaker, 1 No. neutral earthing transformer breaker and 1 No. outgoing feeder.

The switchroom interconnector allows the two switchrooms to be connected together when operating as a 10 MW station.

The container is equipped with an auxiliary transformer (for site power) air conditioning (for switchgear cooling) and lighting.

Diesel Fuel Tanks

Cylindrical diesel fuel tanks are offered as required. These are fitted into standard ISO spaceframes.

Each tank has a capacity of 22,000 litres.

10 No. such tanks will provide approx 6 days operation at full load.

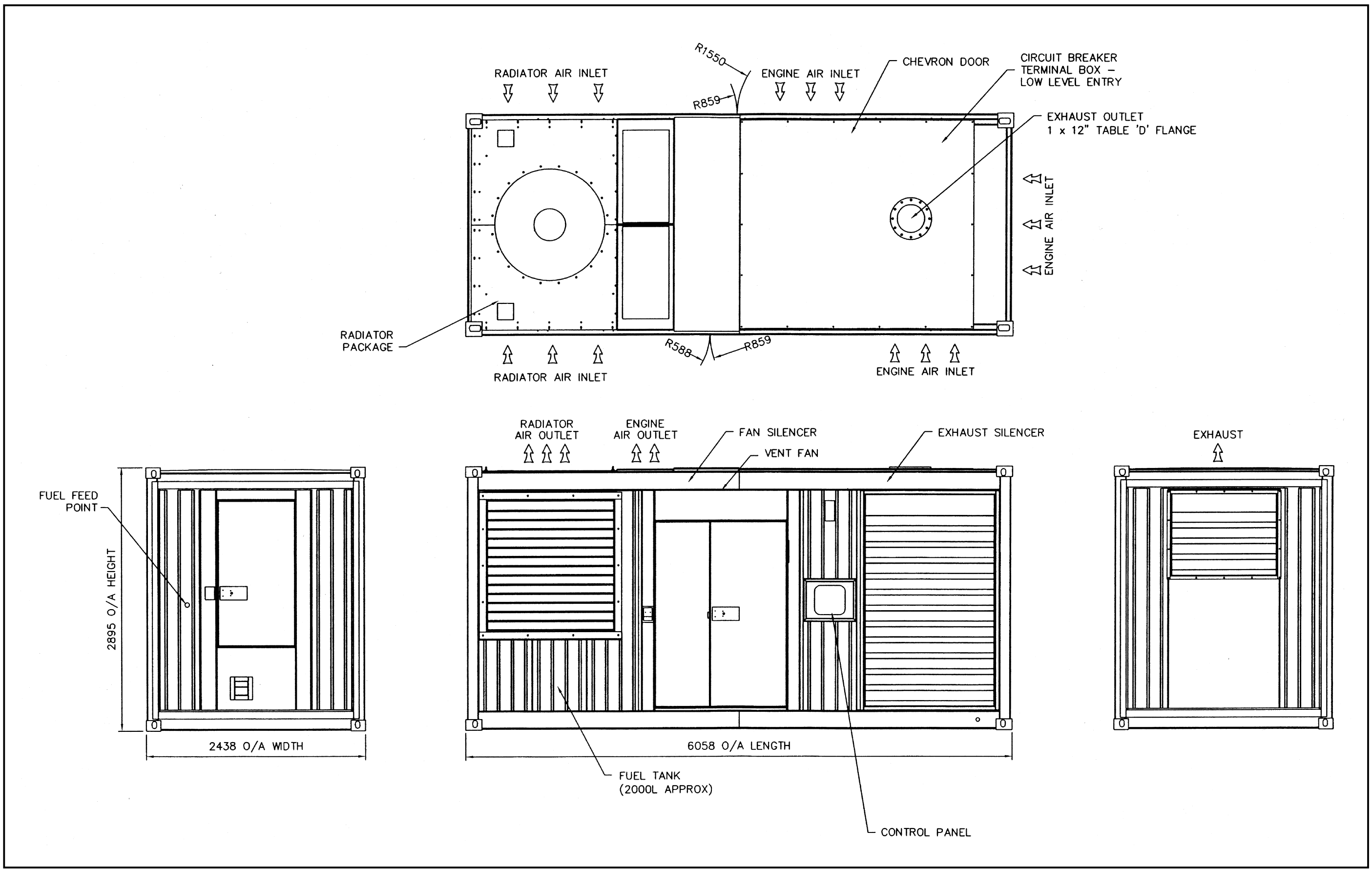
A fuel transfer pump is offered (suitable for 50/60 Hz). This provides a pressurised fuel feed to each set.

Control Room

The control room is also housed in a 20ft (6m) standard ISO container and is equipped with all necessary control and surveillance equipment.

Start, stop and monitoring are done from a desktop pc.

The container provides a small office and a control area and is equipped with air conditioning and lighting.



Containerised 1 MW generating set package.

Typical 30 MW Cummins Power Station being installed on a site in Africa.

Multi-set installation with 28 x 1 MW generators would produce 20 MW continuous output.

Transportation, offloading and installations are all carried out by Cummins on every site. Operation and maintenance for all equipment on site can be undertaken by Cummins.

5 MW or 10 MW Power Modules

Example of 5 MW Power Station Module with 7 x 1 MW Generating Sets. Note 6m (20ft) container packs for transformers, control and switchgear. Stacked on right hand side are 22000 litre fuel tanks in 6m (20ft) packages.

ExCel Exhibition Centre - London

CHP Installation for ExCel Centre

A 1.35MW CHP installation provides London's biggest exhibition centre - ExCel in Docklands - with a complete heating, power and air-conditioning solution.

Operating continuously in parallel with the limited grid supply, the unit provides a cost-effective alternative to reinforcing the national grid.

Waste heat from the exhaust system is used to provide medium hot water for heating in the winter and in the summer, chilled water for air-conditioning.

Power Generation

Cummins Gas Projects Division has installed a 1.35MW CHP generating set to supply heating and air-conditioning for the new £250 million ExCel Exhibition Centre in London's Docklands.

Operating 365 days a year and 24 hours a day, the CHP unit is able to supply medium hot water generated by waste heat from its exhaust, which in winter is used for heating and in the summer months, via an absorption chiller for air-conditioning.

Energy Centre

The Energy Centre, which is operated by Scottish & Southern, also contains two diesel-powered standby generating sets that can be used in peak lopping mode for up to 250 hours a year.
The CHP set operates in parallel with the Centre's electricity grid supply ensuring on-site baseload during peak periods, such as when exhibitions are being held.
The ExCel Energy Centre also includes three 6MW boilers, two 2.5MW absorption chillers, and one 3.9MW vapour compression chiller. In the event of a mains power failure, the CHP unit is automatically stopped and a circuit breaker is opened isolating the unit. It then provides standby in parallel with the Energy Centre's two standby sets.

World-class

Covering an area of 90,000m^2 ExCel provides London with a world-class, state-of-the-art venue for conferences, exhibitions and special events.
This new structure - which is larger than the nearby Millennium Dome - has broken a number of records by becoming the largest single roofed structure in the UK, and the largest single building for the UK's events industry.
ExCel also forms the largest clearspan building in Europe and required a total of 96 x 87m-long trusses to span the 375m-long halls. One of the venue's dominant features is the external 40m-high mast structure constructed to enable the roof to span the full width of the exhibition halls without any internal columns.
Situated alongside the Royal Victoria Dock, ExCel's design incorporates a waterfront promenade overlooked by cafes, bars and restaurants. It will also be part of an impressive environment that will eventually include seven hotels with 1,500 rooms, 500 apartments, as well as 20,000m^2 of retail outlets.
In terms of power supply the Docklands area posed a serious problem for ExCel's developers. As there is only a limited grid supply, and reinforcing the national grid was deemed to be too high, ExCel brought in Energy Control Consultants Ltd (ECCL) to formulate an energy strategy.

Cost Effective

As an exhibition centre, modelling for the ExCel site showed complex demand patterns that varied significantly depending on two factors: weather temperatures outside, and the internal use.
The chosen and most cost-effective and efficient configuration for the site involved using CHP plant for the baseload topped up by the limited grid supply to make up the core off-peak load.
Scottish and Southern put the consultants' proposal into practice, installing a 7MW grid supply including two 3MW diesel-powered generating sets and one Cummins 1.35MW CHP set powered by a 16 cylinder 16QSV81G 81-litre gas powered Cummins engine.
The Cummins set now runs continuously. Cummins has a 15-year contract to undertake responsibility for all maintenance.

Mini Power Station - Nairobi, Kenya

Power Station relocated in 12 weeks

The versatility of **Cummins Power Rental** containerised power stations was admirably demonstrated by relocating thirty nine sets from Ghana to Kenya - on the other side of Africa - in just twelve weeks.

The total project included fuel lines, tanks, cables and switchboard controls.

Cummins relocates 30MW power station from Ghana to Kenya, providing a rapid solution to grid shortfall.

Cummins Power Generation demonstrated the versatility and portability of its containerised mini-power stations by relocating a 30MW installation from Ghana to Kenya in less than 12 weeks. It took just 9 days to offload, transport, install and commission the sets, once the ship arrived in port.

The power station is operating 24 hours a day feeding into an existing sub-station at Embakasi in the Kenyan capital Nairobi. It will generate electricity for the Kenya Power and Lighting Company (KPLC) for a period of six months.

“Kenya had a serious situation that was getting worse,” explained Cummins’ operations manager on site.

“Some 60-65% of the country’s power is hydroelectricity. But last year water levels were extremely low. The rainy season, from March to May, came and went without any rain. To make matters worse, there had been droughts at the end of the previous year.”

“The result was power rationing lasting 18 hours a day, even in Nairobi. It was a big problem that was affecting industry, business and domestic users, and costing KPLC several million dollars in lost revenue.”

The World Bank stepped in with funds for the purchase of energy, and the government signed three contracts to purchase a total of 105MW of power.

Rapid Deployment

The 39 generating sets met a critical deadline, commissioning all sets, on-line, on-site in 12 weeks from order. It took Cummins just nine days to offload, transport some 300 miles to site, install sets, 21 km of fuel lines, tanks and cables, distribution switchboard controls, transformers and commission all sets.

The sets will be generating power 24 hours a day for Cummins customer, Kenya Power & Lighting Company and feeding power into their substation at Embakasi.

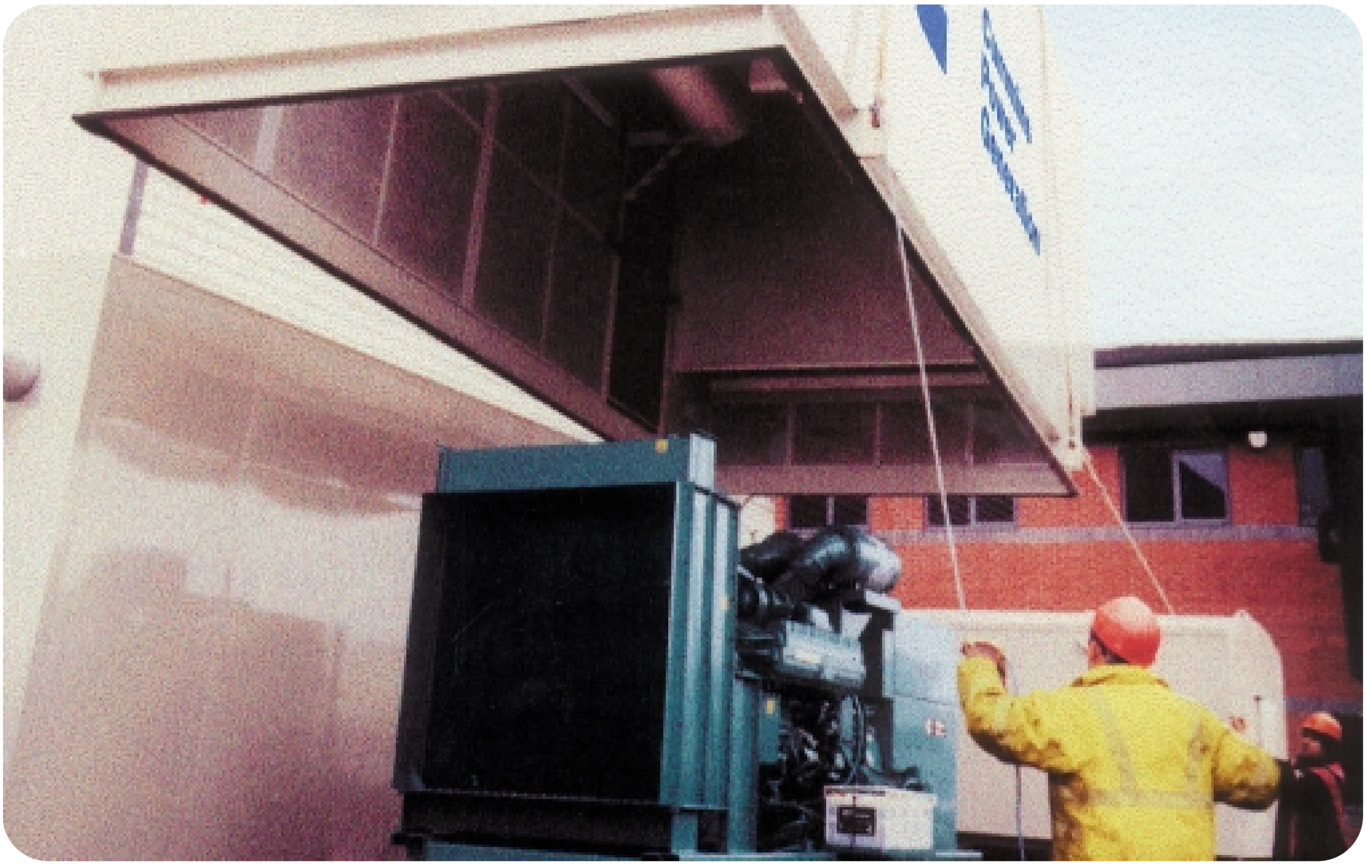
All automatic synchronising and paralleling duties are handled by Cummins microprocessor digital PowerCommand™ Control (PCCP) system with a MTBF (mean time between failures) of 250,000 hours.

Each set produces 1043 kVA, 834 kW, at 50 Hz, running at 1500 rpm transforming from 3300 Volts up to 11,000 Volts for connection to the grid. The station has 36 sets working 24 hours a day, seven days a week, producing 30 MW - with backup capacity of three generating sets on standby; to allow for a scheduled maintenance programme.

The system is networked for local monitoring with access from the Cummins factory in Kent, England some 4828 km away.

Cummins Power Generation

NEXT Distribution Centre – Yorkshire, UK



Two 800kVA fully automatic standby sets

The UK major retailer, NEXT have installed two 800kVA fully automatic standby sets at their automated warehouses in South Emsall, Yorkshire.

They are powered by Cummins QST30 twelve cylinder engines to protect the warehouses against power supply problems from the National Grid.

They feature the new PowerCommand Control system and are in constant standby mode.

Two Cummins Power Generation 800kVA sets have been installed at leading home shopping and High Street brand Next's new 21,368 sq.m. fully automated main distribution and warehouse centre; bringing its total standby back-up to 10 sets. All of them supplied by Cummins Power Generation and subsidiary companies.

Comprising two 800kVA generating sets and ancillary control and switching gear, the system will protect the centre from supply faults in the National Grid. A power cut or severe reduction in voltage could have serious consequences in the fully automated distribution centre which will receive boxed goods into store and then pick and despatch orders for the company's 300 stores nationwide.

"Our retailing operation demands a high turn round of orders as many of our stores do not have the facility to carry large stocks. In addition, we pride ourselves on providing a first class service to shoppers who buy from home with the Next Directory," said a Next spokesman.

Automated Distribution

Equipped with 20m high-bay storage racking and sophisticated conveyor and order collating systems, the distribution centre will be one of the most advanced of its kind in the UK.

"This high degree of automation, and the requirements of a fully computerised order processing and administration operation, means we simply cannot afford to be without power, even for a short period. Having an excellent standby system was therefore a priority when we planned a new centre," said the spokesman.

The Cummins Power Generation sets are installed alongside one of the building's exterior walls and supplied by diesel drawn from an adjacent 28,000 litre tank. Highly efficient acoustic enclosures reduce operating noise to a minimum and ensure full protection against the elements.

Automatic and Seamless

The sets powered by the latest Cummins QST30G2 engines and featuring the new PowerCommand control system, will be in constant standby mode and monitor the National Grid supply. When a failure is detected the Cummins generating sets will take over and be capable of supplying the distribution centre with its full power requirement within 5-10 seconds of start-up. And, because the standby system works in parallel with the grid supply, it switches off automatically when normal power is restored. This also allows the system to be tested without interfering with normal power supplies.

"What we have is an assurance of virtually seamless power supply which takes away the risk of backlogs and delays in order processing and despatch caused by a failure. Consequently, we see this system as not simply a vital operational advance but also an investment in further improving our already high level of customer service," said the spokesman for Next.

The Cummins Power Generation sets and control system were selected from a number of competitive bids because they were the company who offered the most in terms of the particular package that Next required. The latest standby installation brings the company's tally of gen-sets to 10 units.

Barclaycall Financial Centre – Sunderland, UK

No break – seamless mains return

Cummins Power Generation has installed two 1250kVA (1000kW) CP1250-5 generators at the Barclaycall building at Doxford, Sunderland.

They have automatic starting, automatic load sharing and mains parallelling and are controlled by PCC – PowerCommand Control and DMC300 Digital Master Control systems.

Case History

Power Generation

The Site

At the impressive Barclaycall building at Doxford Sunderland Cummins Power Generation has installed 2 x 1250 kVA fully automatic standby sets for Barclays latest Financial Service to all their customers.

The location is the centre for Barclays Help Desk and Financial Advice Centre. Standby power from the generating sets protects, all computers, data banks, lighting and essential support systems such as UPS back up throughout the two 3 and 4 story buildings.

The Control System

Both CP1250 kVA generators are equipped with Cummins PCC (PowerCommand Control) systems linked into a DMC 300 (Digital Master Control) system to provide automatic starting on a voltage dip or complete mains power loss. Automatic synchronising and load sharing between the two generators with mains parallelling ensures a no - break or seamless return to the mains when power is restored. Both systems are microprocessor controlled and the DMC incorporates the latest touch screen facia for monitoring, control and programming commands.

Two incoming mains feed into the distribution system which is split into essential and non - essential Loads. All power is initially fed into “essential” loads on start up.

The Sets

The sets are powered by Cummins KTA50G3 sixteen cylinder turbocharged diesel engines driving Cummins - Stamford brushless alternators with PCC control systems.

Installation

Electrical Contractors N. G Bailey were responsible for the electrical contract throughout the building and installing the generators.

Ten other Barclay Bank major premises throughout the United Kingdom are also protected by Cummins standby sets.

The King Faisal Hospital – Riyadh, Saudi Arabia

Seven sets for Specialist Hospital

Cummins Power Generation have installed seven generators to provide total power for the specialist hospital and research centre in Riyadh, Saudi Arabia.

They comprise of 4.6MW with four 700kW (875kVA) and three 600kW (750kVA) gensets with continuous base load operation, automatic synchronising and load sharing. They are powered by Cummins VTA28 and KTA38 twelve cylinder diesel engines.

Cummins Power Generation installation provides 4.6MW prime power for Saudi Arabian hospital.

Seven Cummins generating sets with a combined output of 4.6MW are supplying 100% prime power to a large hospital in the Saudi Arabian capital Riyadh.

The Power

The installation at the King Faisal Specialist Hospital and Research Centre comprises four 700kW (875kVA) and three 600kW (750kVA) sets each with a 380V, 60Hz output. Typically there will be four or five units operating at any time, with the others on standby. The control panel, located on a adjacent room, automatically synchronizes the output and maintains a load of 70-80% of full capacity on each generator. This is to optimize the working life of the set. The control system also ensures that as each set starts it will take the critical load immediately.

Cooling is via roof-mounted remote radiators.

Long term reliability

The sets were installed in 1993 by local Cummins distributor General Contracting Company (GCC Olayan) to replace seven competitive units that had proved unsuitable for the task.

To date they have clocked up more than 17,000 hours.

YOUR LOCAL DISTRIBUTOR

Cummins Power Generation Limited
Manston Park, Columbus Avenue
Manston, Ramsgate
Kent CT12 5BF, UK
Tel: +44 (0)1843 255000
Fax: +44 (0)1843 255902
Email: cpg.info@cummins.com
www.cumminspower.com
www.cummins.com

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