TECHNICAL SPECIFICATION

STATIC AC UNINTERRUPTIBLE POWER SUPPLY UNIT (STATIC AC UPS UNIT)

DEP 33.65.50.32-Gen.

December 1998

DESIGN AND ENGINEERING PRACTICE

PREFACE

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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for a static (semi-conductor) A.C. Uninterruptible Power Supply (UPS) unit comprising rectifier, battery, inverter and static bypass switch.

This DEP is a revision of the DEP of the same number dated October 1989.

The unit as specified is required to serve as a secure (uninterruptible) alternating current source of power to vital instrumentation and safeguarding systems that perform a controlling, monitoring and safeguarding function in continuously operating plants.

1.2 DISTRIBUTION AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F" as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements are more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project, or operation or maintenance of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The **Purchaser** is the party which buys the Static UPS Unit. The Purchaser may be either the Contractor or the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Autonomy Time	The specified time that the battery shall be capable of supplying rated current to the inverter within the specified voltage limits.
Battery design capacity	The battery power required (BDCW) as determined by the battery calculation specified in Appendix 4.
Bypass supply	The alternative mains supply connected directly to the static switch to provide a standby supply to the load in the event that the inverter output is out of limits.
Conditioned room	A ventilated room where provisions have been incorporated to minimise dust ingress and maintain an equable temperature
Crest factor	The ratio of the peak value to the r.m.s. value of the total periodic waveform.
C_{10}	The nominal battery capacity based on a 10 hour discharge rate at 20 °C.
Discharged condition	The condition reached when the battery has been discharged to the point that the inverter can no longer deliver its rated output within the permissible output tolerances.
Equalisation charge or Commissioning/ Initial charge	The passing of an electric current through a vented battery by applying a higher voltage to equalise and realign the voltage distribution across the battery string. This is normally carried out with the battery off line.
Float charging	The passing of an electric current through a battery by applying a constant voltage from a charger such as to maintain the battery in a state of charge.
Inverter supply	The normal output of the UPS Unit via the rectifier/battery/inverter string.
Low maintenance nickel cadmium batteries	Valve regulated type nickel cadmium batteries designed for ultra low maintenance and which also require a controlled maximum charging voltage.
Maintenance bypass switch	A manually operated switch incorporated into the UPS Unit to provide a supply to the load in such a way that the main components of the UPS unit become isolated and voltage free.
MTBF	Mean Time Between Failure.
MTTR	Mean Time to Repair.
Power factor	The power factor of the fundamental wave, cos ϕ, (sometimes referred to as the displacement factor) imposed by the combined effects of the UPS load characteristics and its harmonic content.
High rate charging	The passing of a constant electric current through a battery by applying a controlled voltage from a rectifier, so as to restore the battery to a predetermined state of charge in a limited timespan, usually applied after a period of deep discharge.
Rated output	The apparent power, expressed in kVA, which can be continuously delivered by the unit over the range of conditions of service and electrical loading specified in this document, without exceeding component ratings or any of the required output tolerances.

Relative harmonic content

The ratio of the r.m.s. value of the harmonic content to the r.m.s. value of the total non-sinusoidal periodic waveform, as follows:

$$\text{relative harmonic content} = \sqrt{1 - (g_1 / g)^2}$$

where g_1 = r.m.s. value of the fundamental component of current or voltage

and g = r.m.s. value of the total waveform of current or voltage.

UPS

An Uninterruptible Power Supply unit consisting of a rectifier, battery, inverter string with a static switch connected to a bypass supply.

Vented, flooded, batteries

Battery cells incorporating free liquid electrolyte in an enclosed container having one or more vents through which gaseous products may freely pass, and which can accept high rate charging following a discharge (can be lead acid or NiCd).

Vital service

A service which, when failing in operation or when failing if called upon, can cause an unsafe condition of the process and/or electrical installation, jeopardise life, or cause major damage to the installation.

VRLA Batteries

Valve regulated lead acid, battery cells in containers which are sealed under normal conditions, and in which the electrolyte is absorbed in plate separator material such that oxygen evolved from the positive plates transfers to the negative plates and `recombines' to form water. The containers incorporate a pressure relief device to permit the escape of gas if the internal pressure exceeds a certain value. The cell charging voltage on VRLA cells needs to be strictly controlled and high rate charging is not permitted.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced in this DEP are listed in (8).

2 GENERAL REQUIREMENTS

2.1 BASIC STANDARDS

The UPS unit shall comply with IEC 60146, EN 50091 and this DEP. In the event of conflict, this DEP shall take precedence.

UPS systems for installation in countries which are part of the European Union (EU) Trading Area shall comply with the applicable EU directives and shall be supplied with the required CE certification and markings. For other areas, equivalent certification shall be provided together with any additional requirements necessary to meet local regulations or as otherwise specified by the Principal.

Equipment specific requirements shall be as detailed in requisition DEP 33.65.50.94-Gen issued by the Principal. The UPS supplier shall then provide the vendor information requested in the requisition by completing the document and returning it with the tender.

In case of conflict between documents relating to the enquiry/order the following priority of documents shall apply:

1. purchase order;
2. requisition and project specification;
3. this DEP.

2.1 DESIGN BASIS

The UPS shall be of the electronically regulated type. Units incorporating magnetic stabilisers (e.g. constant voltage transformers) are not acceptable.

The design of the UPS shall be such as to minimise the risk of short circuits and shall ensure personnel and operational safety at all times.

The electrical load to be energised by the UPS comprises a high proportion of digital electronic equipment incorporating switched mode power supply units which exhibit non-linear characteristics.

UPS units are normally installed in conditioned rooms, unless otherwise specified.

The design and selection of equipment and components shall be based on achieving the following minimum lifetimes:

- 20 years for rectifier, inverter, static switch and associated auxiliaries;
- 4 years' continuous operation for rotating equipment, e.g. cooling fans;
- 8 years for capacitors of the electrolytic type to retain the capacity needed to operate within the specified tolerances;
- 20 years for NiCd and vented Lead Acid battery cells when operating in an average room ambient temperature of 25 °C;
- 10 years for VRLA battery cells when operating in an average room ambient temperature of 20 °C.

Additionally, the UPS shall be designed to operate totally maintenance free for a 4 year continuous period.

All components shall be of a quality and reliability that satisfies the requirements of a secure A.C. source of power to vital equipment performing a controlling, monitoring and safeguarding function in continuously operating petrochemical process units, production facilities and utility installations.

Components shall be capable of withstanding the thermal and dynamic stresses resulting from internal and external short circuits and circuit switching operations etc. Damage arising from component failure should be confined to the component concerned. Component materials shall be non-flame propagating, wherever practicable.

For tropical applications, the UPS components shall be suitably protected against moisture and fungus.

2.2 OPERATING PRINCIPLE

2.2.1 Single static UPS unit

For a single static UPS unit, the circuit arrangement shown in Appendix 1 shall apply.

The output of the rectifier shall continuously supply the power requirements of the load via the inverter, while simultaneously maintaining the battery charge in the float charge mode. In the event of an interruption or depression in the A.C. mains voltage to the rectifier, the battery shall supply the power requirements of the load, via the inverter, for not less than the autonomy time as specified in the requisition.

Upon restoration of the A.C. mains voltage, the rectifier shall supply the power requirements of the load, via the inverter, while simultaneously recharging the battery. The rate of recharging the battery shall be such as to restore it to the required capacity within the time specified in (3.1).

The output of the inverter shall be maintained within the voltage and frequency tolerances as defined in (3.3). The output voltage of the inverter shall also be controlled to maintain synchronism and phase with the bypass supply voltage, provided the latter is within the tolerances specified for the load transfer conditions. If the bypass supply voltage exceeds these tolerances, then the inverter shall revert to unsynchronised operation at its own internally set frequency. The inverter shall automatically resume synchronous operation with the bypass supply when the voltage and frequency of the latter returns within the specified tolerances.

Under synchronous operating conditions, the static switch shall initiate uninterrupted transfer of the load to the bypass supply in the event of deviation in the inverter output voltage or frequency outside the permissible tolerances specified in (3.4), or the switching off of the inverter unit.

In the event of automatic transfer of the load to the bypass circuit and subsequent restoration of the inverter output quantities to within the permissible tolerances, the inverter shall automatically resume synchronous operation with the bypass supply and shall initiate uninterrupted retransfer of the load to the inverter.

A make before break maintenance bypass switch shall be provided for each unit to allow the load to be transferred manually to the bypass supply whilst the UPS unit, including the static switch, is voltage free to allow maintenance to be carried out safely without exposure to live components (assuming the battery isolation switch is also opened).

Facilities shall be provided with clear instructions, adequate warnings and built-in safeguards to enable manual initiation of uninterrupted transfer of the load from the inverter supply to the bypass and from the bypass to the maintenance bypass and back again.

The UPS shall be capable of energising the load within the permissible tolerances and of achieving the uninterrupted load transfer requirements via the static switch, without the battery connected.

Single UPS units shall also be suitable for future upgrading for parallel operation, if required.

2.2.2 Duplicate static UPS unit

Where two independent sources of uninterruptible power are required, the arrangement shown in Appendix 2 is preferred. In this arrangement, two identical fully segregated 100% rated UPS units provide duplicate uninterruptible power supplies to systems incorporating duplicate (switched mode) D.C. power regulators so that the A.C. uninterruptible supply circuits derived from the two UPS units do not operate in parallel with each other. The rated output of each unit shall not be less than the maximum load that will be transferred to it upon total failure of the other UPS.

With the duplicate arrangement shown in Appendix 2, the principle of operation of each individual UPS shall be in accordance with that described for the single UPS arrangement shown in Appendix 1.

2.2.3 Parallel static UPS unit

Where duplicate UPS units are required to provide a single source of uninterruptible power, the arrangement shown in Appendix 3 may be considered. In this arrangement, two identical fully segregated 100% rated UPS units operate in parallel to energise a single switchboard to which the load circuits will be connected. Dual redundant control circuits shall be included to facilitate equal sharing of the load between the two units. The load sharing controls shall not be subject to common mode failure and any failure of the load sharing controls shall not result in the loss of vital power. Each unit shall have a static switch connected to a separate bypass circuit, the rating of which shall be the same as that of each unit. The two bypass supplies shall be connected in parallel from the same mains supply bus bar.

Suitable protection shall be incorporated to safeguard against loss of synchronism during bypass supply deviations which could result in short circuiting of the UPS output.

The principle of operation of the duplicate parallel arrangement shown in Appendix 3 is as described above for a single UPS, amended as follows:

Each unit shall effectively run at 50% duty. Failure or switching-off of any one inverter shall result in uninterrupted acceptance of the complete load by the other inverter, and thereafter to the bypass circuit in the event of subsequent failure or switching-off of the second inverter.

Other equivalent configurations to Appendix 3 may be considered by the Manufacturer to meet the operational requirements defined above.

2.3 UNIT RATING

Unless specified otherwise by the Principal, UPS units having rated outputs up to and including 30 kVA should have 1-phase and neutral output, and units having a rated output in excess of 30 kVA should have 3-phase and neutral output. In all cases the rectifier input supply shall be three phase, 3 wire and the separate bypass supply shall be 4 wire, 3 phase or 2 wire, 1 phase, as appropriate.

The neutral of the A.C. output shall be solidly earthed.

The UPS shall be rated to continuously energise the load at a load power factor of 0.8 lagging while maintaining an output voltage within the permissible tolerances as defined in (3) and satisfying the operational requirements specified in this document. The unit shall also be capable of energising loads between 0.7 lagging and unity power factor within the specified tolerances, providing these fall within its kW/kVA rating.

The UPS unit shall be capable of supplying a load consisting of principally computer and/or digital electronic equipment incorporating switched-mode power supply units which may have a crest factor of up to 3.

2.4 SERVICE CONDITIONS

Unless otherwise specified in the requisition, the UPS shall be located inside a freely ventilated room or module in which the following conditions apply:

- average ambient air temperature : 20 °C to 25 °C
- maximum ambient air temperature : 40 °C
- relative humidity not exceeding : 90%
- altitude not exceeding 1 000 m

VRLA batteries shall be designed for operation in a nominal ambient temperature of 20 °C, but shall be capable of operating for limited periods in the temperature range 10 °C - 30 °C, unless specified otherwise.

NiCd batteries shall be designed for operation in a nominal ambient temperature of 25 °C, but shall be capable of operating for limited periods in the temperature range 0 °C - 40 °C, unless otherwise specified

2.5 MAINS ELECTRICITY SUPPLY

The UPS shall be capable of operation with the nominal voltage and frequency as indicated in the requisition and on the basis of the following:

The input supply variations shall be limited under steady state conditions to:

- nominal system voltage : plus 10% and minus 10%
- nominal system frequency : plus 5% and minus 5%

The AC power supply to the UPS will be symmetrical and sinusoidal within the limits defined by IEC 60146-1-1, Immunity Class B, although the input voltage may be subject to transients comprising short term voltage depressions up to 20% of nominal during motor starting, and to voltage interruptions during system short circuits. Transient high frequency voltages of up to 2 kV may also be superimposed on the input voltage as a consequence of system switching operations.

2.6 TIE-IN OF UPS UNIT TO ELECTRICAL SUPPLY SYSTEM

The Manufacturer shall specify the current rating of general purpose fuselinks (type gG, in accordance with IEC 60269-2) which the Principal shall provide in the mains supply switchboard for energising the rectifier and bypass circuits. The fuse rating shall be based on meeting 150% overload at minimum battery volts and include for UPS unit efficiency.

The Principal shall provide all the interconnecting cables between the UPS and external equipment such as switchboards, including those to the battery, unless specified otherwise.

For the parallel redundant configuration, Appendix 3, all control bus cabling/wiring shall be supplied by the Manufacturer.

All batteries shall be located in a suitably conditioned environment separate from the UPS. The Manufacturer shall specify the size of the conductor required for the battery cables, based on a cable length not exceeding 20 m, or as otherwise specified in the requisition.

The Manufacturer shall provide a suitable, lockable, fused load-switch, MCB or MCCB to facilitate on-load isolation of the battery for the purpose of performing battery maintenance. The MCB or MCCB shall be in accordance with IEC 60947. The switching device shall be installed adjacent to the battery, and shall be suitably classified for hazardous area operation.

If the nominal output voltage of the UPS is different from that of the mains supply, the Manufacturer shall provide a double wound transformer in the bypass circuit. For single phase units the transformer shall be connected across two phases of the three phase supply; in both cases the secondary winding of the transformer shall be earthed.

2.7 INFORMATION TO BE SUBMITTED WITH THE TENDER

The Manufacturer shall submit a technical specification of the UPS which shall include a description of the design, operation, construction, performance and maintenance aspects of the equipment, and list all deviations from this specification.

The information shall include relevant calculations of the nominal battery capacity and the number of battery cells that are needed to meet the specified performance requirements of the UPS as defined in (3.3) and Appendix 4.

The Manufacturer shall also submit the information requested in the requisition by completing the document as specified and returning this with the tender.

The Manufacturer shall include sufficient spare parts to fully cover the on site commissioning activities. In addition, if specified in the requisition, the Manufacturer shall provide a detailed quotation for 2-year operation spares.

For technical support and servicing at site, the Manufacturer shall indicate the nearest service organisation recommended for the location at which the static UPS will be installed.

The Manufacturer shall also submit details complete with pricing of their standard service contracts with the following selectable options :

- maintenance service contract based on periodic servicing of the unit;
- the above, plus breakdown coverage with site call out and support;
- full service contract with full spares coverage.

3 PERFORMANCE REQUIREMENTS

3.1 RECTIFIER

3.1.1 General

The rectifier shall operate according to the constant voltage, current limiting principle and shall incorporate a soft-start feature to gradually accept load on initial energizing. The rectifier shall restart automatically upon restoration of the mains power supply following a supply interruption

The rectifier shall be rated to recharge the battery within 10 hours following a discharge at rated load for the specified autonomy time, whilst at the same time meeting the inverter input requirements when the inverter is delivering its rated output at 0.8 power factor lagging.

For vented types of battery, the rectifier shall perform battery charging at the dual rate corresponding to the float charge and high rate charge requirements. For VRLA and low maintenance NiCd batteries, the rectifier shall perform battery charging in accordance with the operational stipulations of the battery supplier and no high rate charge facilities shall be provided.

For vented NiCd batteries, the rectifier shall also be capable of delivering the battery initial equalisation charge as specified by the battery supplier.

The re-charge performance specified above shall be achieved irrespective of the type and method of battery recharging employed.

3.1.2 Rectifier input

The UPS unit shall be capable of operating from the mains electricity supply as defined in (2.5).

The harmonic current consumption shall be calculated based on the maximum short circuit capacity at the LV switchboard bus bars as defined in the requisition, so that the overall harmonic current levels shall not exceed the values as defined in IEC 61000-3-2, or as otherwise specified by the Principal. If the short circuit capacity of the supply is not known, the calculation shall be based on a short circuit capacity of the supply system of 40 times the kVA rating of the UPS unit.

Transients and surges on the mains input, as defined in (2.5), shall not result in a trip of the rectifier unit or the initiation of battery discharge.

3.1.3 Rectifier output

Under all operating conditions the voltage AC component ripple on the battery terminals, including any ripple from the inverter and load, shall be limited to a value which ensures the peak to peak current ripple for VRLA batteries shall be less than 1% of the battery C_{10} value, and less than 5% for NiCd batteries.

The D.C. supply shall not be utilised to energise loads other than the inverter.

3.1.4 Temperature compensation

For VRLA batteries, temperature compensation of the battery charging voltage shall be provided for the rectifier, with an accuracy of plus and minus 1%. The temperature sensor shall be located in the centre of the battery rack and shall adjust the rectifier output voltage in line with the battery Manufacturers' recommendations. Temperature compensation shall also be considered for other batteries in locations where sustained ambient temperature variations in excess of plus or minus 5 °C are expected.

3.1.5 Battery float-charge operation

The rectifier steady-state D.C. output voltage variations shall be controlled to within less than plus and minus 1% of the set value of the temperature compensated battery float-charge voltage specified by the battery Manufacturer during load variations between zero

and the rated output of the rectifier. This shall be achievable throughout the range of steady-state input voltage and frequency variations defined in (2.5).

3.1.6 Battery high rate charge operation

For vented batteries only, facilities shall be provided to initiate battery high rate charge operation by both manual and automatic means.

Automatic initiation of battery high rate charge operation shall occur following any period of battery deep discharge which would result in the application of current limiting recharging.

The application of high rate charging shall continue until the battery is fully recharged.

3.2 BATTERY AND D.C. CIRCUIT

3.2.1 General

The battery voltage and capacity shall be such as to fulfil the inverter input power requirements when the inverter is delivering its rated kVA output at 0.8 power factor lagging, for the autonomy times specified in the requisition.

The battery discharge performance shall be fulfilled as follows:

- throughout the range of service conditions as specified in (2.4), including that corresponding to the average cell temperature specified in the datasheet;
- during repeated cycles of the battery from the fully charged to the partially discharged condition and subsequent restoration as defined in (2.2); and
- following at least 4 years' continuous operation under battery float-charge conditions.

The nominal ampere-hour capacity of the battery supplied with the UPS shall be calculated in line with the battery sizing calculation defined in Appendix 4 and shall include all necessary allowances required to compensate for ageing effects that result in the progressive loss of capacity.

VRLA batteries shall be classified to BS 6290-4, category 1H23 minimum, or equivalent.

Parallel battery strings shall be provided for all VRLA batteries utilised on UPS units above 10 kVA, unless specified otherwise. Parallel battery strings shall be arranged so that all the batteries are of the same capacity with the same number of cells connected with identical cable lengths, cross sections and materials from the branching point. Each battery string shall be provided with a lockable battery isolation switch.

The batteries shall be located separately from the UPS unit in a suitably conditioned environment on free-standing support racks which may be of steel or wood, or equivalent. All wood should be treated to render it non-hygroscopic and acid resistant. Steel racks shall have a plastic or epoxy coating to provide suitable protection against the effects of electrolyte spillage.

The batteries shall be positioned so that possible leakage of electrolyte or emission of gaseous products shall not cause damage to other equipment, components, or adjacent cells.

Battery spacing for VRLA cells shall be a minimum of 10 mm to ensure an even temperature distribution. Vertical separation between layers shall be sufficient to permit free and safe access for cell measurements and/or replacement.

3.2.2 On-line battery monitoring and testing

All UPS units shall be provided with online battery circuit monitoring facilities which maintain a continuous assessment of the overall condition of the battery string under normal operating conditions and provide an alarm when this falls outside prescribed limits.

For VRLA batteries, the monitoring facility shall also measure voltage levels of blocks of cells within a battery and shall alarm at a pre-set voltage level (high and low) which indicates under performance of a particular block of cells.

If specified by the Principal, for UPS units with large batteries in critical service, the battery monitoring facilities shall also incorporate provision for individual cell measurement, recording and alarm.

For VRLA batteries and, if specified in the requisition, other battery types, the UPS shall also provide for on-line battery testing by means of a short duration battery discharge into the load, either manually or automatically. The facility shall be programmable to define the automatic testing periods and the level of discharge. The monitoring system shall compare the discharge values with the actual pre-programmed battery discharge characteristics and shall be capable of providing a detailed analysis of the battery condition. Additionally, provision shall be included to manually select a full battery discharge test.

3.3 INVERTER

3.3.1 General

The inverter shall be of the current limiting type (short circuit proof) and have nominal output voltage and frequency as specified in the requisition. The inverter output voltage and frequency shall not exceed the operational tolerances given below, as measured at the output terminals of the unit, during the following conditions of UPS loading:

- Steady state load variations between zero and the rated output of the UPS.
- Load power factors over the range 0.7 lagging to unity within the kW/kVA rating of the unit.
- Load current waveform having a relative harmonic content varying between zero and 50%, the latter waveform having a crest factor not exceeding 3 and individual harmonics not exceeding the following values:

  3rd harmonic - 44% of fundamental

  5th harmonic - 33% of fundamental

  7th harmonic - 18% of fundamental

  9th harmonic - 7% of fundamental

  11th harmonic - 10% of fundamental

- D.C. input voltages over the range corresponding to battery high rate charge, where applicable, and battery discharge operation during the specified discharge times as defined in (4.2).

The inverter shall control the output of the UPS so as to maintain synchronism with the bypass voltage during variations in mains frequency up to the limits specified in para 3.3.5. During variations in mains frequency exceeding these limits, the inverter shall revert to internal frequency control.

3.3.2 Rated output

The rated output of the UPS shall be as specified in the Requisition Datasheet, to standard duty class II of IEC 60146.

3.3.3 Output voltage static regulation

When operating independently of the bypass, the output voltage static regulation shall be maintained within plus and minus 1.5% of rated output voltage. For 3-phase inverters, the phase and line voltages shall not exceed plus and minus 1% of rated voltage when the load current in any two phases differs from the rated output current by up to 50%.

3.3.4 Output voltage dynamic response

The dynamic output voltage variations shall not exceed plus and minus 5% of rated output voltage in the event of instantaneous load changes of 100% rated output. The output voltage shall be restored to within the steady state limits of plus and minus 1.5% of rated output voltage within 0.1 s.

3.3.5 Frequency deviation

Synchronous operation of the inverter and bypass supplies shall be maintained for deviations in frequency of up to plus or minus 5% of mains rated frequency, at a frequency slew rate of up to 0.1 Hz/s, above which the inverter will revert to internal frequency control.

When operating independently, the inverter output shall be maintained within plus or minus 0.5% of nominal rated frequency.

3.3.6 Output voltage waveform

The waveform of the output voltage shall be sinusoidal with a relative harmonic content not exceeding 5% for both linear and non-linear loads, unless stated otherwise in the requisition.

3.3.7 Output voltage symmetry

For 3-phase inverters, the angular displacement of the phase voltages shall not exceed 120° ± 2% when supplying a balanced, linear load at rated output, 0.8 power factor lagging, and 120° ± 5% when the load current in one phase differs by 100% from the rated output current.

3.3.8 Short circuit current and overload

As a minimum the inverter shall be capable of delivering 150% of its rated output for one minute. For fuse clearing and excessive overloads the unit may switch to bypass without interruption to the vital power, unless this is specified otherwise in the UPS datasheet.

3.4 STATIC BYPASS SWITCH

3.4.1 Circuit rating

The bypass load transfer switching device shall comprise continuously rated static elements in the bypass circuit, and the use of short time rated static elements in conjunction with continuously rated contactors shall not be used without the prior agreement of the Principal. No fast acting fuses shall be included in the static bypass circuit, which shall have a continuous current rating equivalent to the rated output of the UPS, and shall be short time rated to meet the following requirements:

- Short circuit on output busbars for 20 ms;
- 1 000% of UPS rating for 50 ms;
- 150% of UPS rating for 1 minute.

In addition, the unit shall be capable of blowing a gl (slow) type fuse, with a rating equivalent to 30% of the rated nominal current of the UPS unit, via the static switch and bypass circuit, assuming an infinite system source impedance.

3.4.2 Load transfer criteria

Facilities shall be provided to manually and automatically initiate transfer of the load from the inverter supply to the bypass supply, and vice versa, without interruption of supply.

The criteria for load transfer shall be as follows:

Transfer of the load from the inverter to the bypass.

Load transfer shall only be possible when:

- The bypass voltage is within ± 10% of rated UPS output voltage, and
- The bypass frequency is within ± 5% of rated frequency, and
- The bypass frequency slew rate is within 0.1 Hz/s, and
- The inverter output and bypass voltages are synchronised.

Automatic transfer of the load shall be initiated when:

- The inverter output voltage drops below 95% of the nominal output voltage. Transfer should be accomplished before the voltage reaches 85% of the nominal value, or
- The inverter output voltage exceeds 105% of the nominal output voltage. Transfer should be accomplished before the voltage reaches 115% of the nominal value, or
- The inverter output current limit is exceeded.

Re-transfer of the load from the static bypass to the inverter.

Load re-transfer shall only be possible when:

- The inverter output voltage is within ± 5% of the nominal output voltage for more than five seconds.
- The inverter output and bypass voltages are synchronised.
- The fault which resulted in the initiation of the transfer has been cleared.

After a number of repeated unsuccessful attempts at re-transfer back to the inverter (minimum 3 attempts within 5 minutes), the automatic transfer of the load to the inverter shall be inhibited and the load shall remain connected to the bypass supply.

It shall also be possible to complete an interrupted transfer when the inverter output is not synchronised to the bypass, which shall be effected within not less than 50 ms and not more than 200 ms.

3.5 RELIABILITY

The hardware, including control circuitry of the UPS, shall be suitable for the temperatures that will occur during full load operation. Sufficient operation of components under test shall be carried out to minimise the possibility of early component or system failures.

The Manufacturer shall provide evidence to confirm the minimum MTBFs of the individual units at 20 °C are as specified below:

Rectifier: 150 000 hours

Inverter: 100 000 hours

Static switch: 200 000 hours

The design of the UPS shall be such that the Mean Time To Repair (MTTR) shall be minimised by the use of self diagnostic and monitoring features, with clearly labelled removable control cards. In all cases, the MTTR shall be less than 8 hours.

The Manufacturer shall maintain full spare parts capability and support, including software for at least 10 years after installation.

3.6 ELECTROMAGNETIC COMPATIBILITY (EMC)

All UPS units shall comply with the requirements for EMC as defined in EN 50091-2, in order to ensure:

- harmonic current emissions in both the power supply input and output of the UPS are controlled within acceptable limits;
- any electromagnetic disturbance generated by the UPS and its individual components do not exceed a level which would affect the correct operation of both radio and telecommunications equipment;
- the UPS has an adequate level of intrinsic immunity to external electromagnetic disturbance to enable it to operate as intended.

3.7 NOISE LIMITS

The measurement of noise levels shall be carried in accordance with ISO 3746 or, subject to the Principal's agreement, another standard. The sound pressure level measured at one metre distance from the UPS, at any position, shall not exceed 70 dB(A) at any load between zero and the rated output of the unit.

If the above values are unobtainable without the use of absorptive materials, precautions shall be taken to limit their effect on cooling, dust deposits and fire hazards.

4. CONSTRUCTIONAL REQUIREMENTS

4.1 ENCLOSURE, COOLING AND ACCESSIBILITY

4.1.1 Unit enclosure

The rectifier, inverter and static switch shall be installed in one or more free-standing, self-supporting steel cabinets forming an enclosure. Each cabinet shall be suitable for operation and maintenance with its rear panel against a wall and with similar units located immediately on both sides.

The enclosure shall provide a degree of protection of at least IP 31 in accordance with IEC 60529, unless specified otherwise. The floor shall not be considered as forming part of the enclosure.

4.1.2 Cooling

Internal cooling of the unit shall be by natural or forced fan assisted air ventilation. The unit shall be capable of continuously delivering its rated output, without switching to bypass mode under normal operating conditions, with any one forced air ventilation fan out of service. Under the latter conditions, the maximum continuous temperature of components shall not be exceeded. All fans shall be equipped with monitoring facilities to provide an alarm in the event of fan failure.

The UPS unit shall not incorporate cooling air filters that require periodic cleaning and/or replacement.

4.1.3 Accessibility and maintenance safety

Items requiring access for maintenance such as cooling fans and AC capacitors shall be located so as to facilitate any required maintenance from the front of the unit. If rear access is required to carry out any form of maintenance this shall clearly be identified in the documentation.

All live terminals of door-mounted equipment having a maximum (peak) voltage of greater than 24 volts shall be shrouded or otherwise protected by barriers to a degree of protection of at least IP20. Barriers shall be of rigid transparent, flame retardant, insulating material to enable the screened components to be identified.

All bare busbars and all live terminals of equipment and components located within the enclosure shall be similarly protected by barriers or shrouds to a degree of protection of at least IP 20, unless adequately recessed within the enclosure to prevent inadvertent contact or short circuit by personnel when performing any standard operations and to enable maintenance of the unit to be safely carried without any possible contact with live parts.

The maintenance bypass switch should be preferably located in a separate cubicle behind a separate door. If the switch is located in the main unit cubicle, it shall be configured so that it is completely electrically segregated from the power electronics, static bypass switch and control circuitry.

All incoming and outgoing cables to and from the unit shall be terminated in the maintenance bypass switch cubicle so that when on maintenance bypass the inverter and static switches and their components are safely isolated.

4.2 ELECTRICAL COMPONENTS

Main circuit switches (mechanical) shall comply with IEC 60947 and be of the independent manually operated air-break type for continuous duty. They shall comply with utilisation category AC23 and DC23 for A.C. and D.C. switches, respectively.

Transformers and reactors shall be of the air-cooled type and shall comply with the relevant parts of IEC 60146.

4.3 EXTERNAL CONNECTIONS

The UPS enclosure shall have facilities for the entry of cables from above or below, as specified in the requisition.

For cable entry from above, the incoming terminals shall be located at the top of the unit, otherwise a separate distribution cabinet shall be used to terminate the incoming cables.

The terminals and gland plates shall be arranged so that ample space is available for terminating the cores of external cables. A minimum of 150 mm from gland plate to terminal block shall be provided for UPS units below 5 kVA, and 200 mm for UPS units above 5 kVA.

If specified in the requisition, additional load terminals shall be provided to facilitate connection of a temporary load to test the UPS unit while the permanent load is energised via the bypass supply circuit.

4.4 EARTHING

An earth rail, with a suitable number of earthing bolts or screws, shall be provided. The earth rail shall be connected to the structure of the cabinet, effectively bonding the entire cubicle. It shall be possible to connect at least two 6 mm^2 earth cables to the earth rail for UPS units below 5 kVA, and two 25 mm^2 for UPS units above 5 kVA.

Electrical conductivity between the exposed, non-current carrying conductive parts of the UPS components and the enclosure, and between the enclosure and the earth rail, shall be arranged so as to maintain effective continuity of protective circuits. Earth bonding conductors shall be utilised between enclosures and doors, and wherever else required to achieve effective protection.

The neutral of the inverter output shall be earthed by a bonded connection to the earth rail within the enclosure.

The gland plate for termination of outgoing cables shall be securely bonded to the earth rail.

4.5 MARKING

All terminals of equipment and components shall be identifiable by numerical or alphabetical markings in accordance with the Manufacturer's drawings. Terminals of input and output supply cables shall be clearly and uniquely marked to indicate the nominal system voltage and the phase/polarity of the supply.

The identification of terminals shall be in accordance with IEC 60445.

The following information shall be inscribed on a non-destructive, corrosion-resistant, indelible name/rating plate attached to the outside of the unit enclosure:

- purchaser's order number;
- year of manufacture;
- name of Manufacturer;
- type and serial number of unit;
- nominal input current and voltage;
- nominal output current and voltage.

All other labels/nameplates shall be of corrosion resistant material with indelible inscriptions in the language specified in the requisition.

4.6 BATTERY CONSTRUCTION AND TRANSPORT REQUIREMENTS

Cell containers shall be manufactured from either steel or non-flame propagating, mechanically shock resistant plastic.

Plastic containers of vented, flooded cells shall permit the electrolyte level to be viewed through the container material.

Vented, flooded cells shall be fitted with flame arresting vent plugs.

Inter-cell connectors and pillar terminals shall be insulated or otherwise provided with

protective covering to prevent inadvertent short circuiting.

Battery cells shall be transported fully in accordance with the Manufacturer's instructions, but in general shall be delivered as follows:

Nickel-cadmium cells shall be delivered filled and charged, but if the cells cannot receive a commissioning charge within 6 months of leaving the factory, then the cells shall be supplied dry and discharged for indefinite storage.

Vented Lead Acid battery cells shall be delivered dry and charged and can be stored indefinitely.

VRLA battery cells shall be delivered filled and charged. These cells must receive a commissioning charge within 2 months of leaving the factory. Air-freighting of cells shall be considered as an alternative to delivery by sea-freight if the above commissioning requirements cannot otherwise be met.

5. MEASUREMENT, PROTECTION AND CONTROL EQUIPMENT

5.1 GENERAL

The UPS shall incorporate all the necessary equipment to enable operation, protection and control of the UPS in accordance with this specification, and to safeguard the unit and its components from the consequences of internal and external short circuits, overvoltages and any main or control circuit malfunctions, howsoever caused.

Operating, status and diagnostic indications shall be provided by liquid crystal displays (LCD) with a keypad driven menu and light-emitting diodes (LEDs).

Each LED/alarm circuit shall have in-built test facilities, with the exception of LEDs associated with PCBs. Failure of an LED/LCD shall not cause UPS maloperation or affect the correct functioning of the remote common alarm signal. Indication by means of filament lamps is not acceptable.

5.2 STATUS INDICATIONS

At least the following indications, in the form of LED/LCDs and/or measuring instruments, shall be provided on the front outside panel of the unit to enable verification of the operational status of the UPS. The indications shall be superimposed on a mimic diagram of the UPS to identify the relevant component or circuit. Additionally these indications should be available for remote signalling via the serial interface specified in (5.5).

- A.C. input supply available;
- alternative/bypass supply available;
- rectifier on;
- inverter on;
- load on inverter;
- load on bypass;
- inverter/bypass synchronised;
- battery on high rate charge (if specified).

5.3 MEASUREMENT

All measuring instruments shall be digital.

The following data shall be provided on the front outside panel via a menu driven LCD display. Additionally, this information should be available for remote signalling via the serial interface:

- D.C. circuit voltage;
- Battery charge and discharge current;
- UPS output voltage per phase;
- UPS output current per phase;
- UPS output frequency;
- Battery Autonomy Time remaining.

5.4 PROTECTION AND ALARMS

The status of the alarm and protection functions shall be visually verifiable by appropriate indicators with first failure feature. Alarms associated with trip functions shall be hand reset.

The following alarm and protection functions shall be provided as a minimum:

- A.C. input phase undervoltage	alarm only
- rectifier failure	alarm and trip rectifier
- D.C. overvoltage	alarm and trip inverter
- D.C. undervoltage	alarm and trip inverter
- charge failure/battery discharging	alarm only
- battery disconnected	alarm only
- inverter failure	alarm and trip inverter
- inverter overcurrent	alarm only
- inverter output voltage deviation	alarm and trip inverter
- inverter/bypass not synchronised	alarm only
- cubicle fan failure	fan failure alarm/pre-alarm
- cubicle/inverter stack overtemperature	alarm and trip inverter

The above alarms shall be appropriately interconnected to a terminal block so as to provide one normally open and one normally closed, potential-free, contacts for remote cabling to a common alarm. Additionally this information should be available for remote signalling via the serial interface.

5.5 ENGINEERING ACCESS AND COMMUNICATION FACILITIES

The UPS shall be provided with a standard RS232 connection facility for connection of a standard Personal Computer. The Manufacturer shall provide all necessary software to monitor, review and control settings on the UPS, on or off line. Facilities shall be provided to change setpoints, prepare or examine an event or alarm log, etc. Access to UPS settings and configuration shall be via a password.

Two levels of access shall be available utilising the software :

Level 1 : View Only

The maintenance engineer or operator shall only be able to view the set parameters and actual data but is not permitted to change any settings.

Level 2 : Settings and Control

The maintenance engineer shall be able to control the UPS, reset all trips and reconfigure the UPS setpoints and protection parameters.

Where specified by the Principal, it shall also be possible to connect the UPS, via either a RS485 or fibre optic link to a DCS or SCADA system for selected analogue and digital data to be made available to a higher level controller. The communication shall function utilising standard MODBUS protocol (master/slave).

In addition, if specified in the requisition, the Manufacturer may be requested to provide a quotation for providing the UPS supplied with an in-built modem, suitable for direct communication via a modem connection to the Manufacturer’s service centre or factory to enable remote fault diagnostics and monitoring to be carried out.

6. INSPECTION AND TESTS

6.1 GENERAL

The UPS Manufacturer shall make available for review by the Principal a quality plan which includes the required inspection and testing of the components, including those of major sub-suppliers.

Prior to despatch, the Manufacturer shall verify by test that the operation of the assembled UPS complies with the requirements specified on the purchase order documents, and shall submit to the Principal a report incorporating measurements and results of all tests performed as defined in (6.2).

If specified in the requisition, a representative of the Principal shall witness the functional tests as defined in (6.2) and shall carry out an inspection of the assembled unit and related documents to verify compliance with the requirements of the purchase order and this specification.

Unless otherwise specified, testing of the assembled UPS at the Manufacturer's works will not include the battery that forms part of the purchase order. UPS tests shall be confined to verifying the performance of the UPS unit and related auxiliaries. Tests to verify the capacity of the purchased battery shall be performed by the Principal as part of the commissioning procedure after site erection.

Prior to the commencement of tests, the Manufacturer shall make all relevant adjustments to the protection and control circuit components of the UPS, as necessary to fulfil the requirements of the purchase order and this specification. The rectifier output voltage and current limits shall be set to the appropriate values for the type and number of battery cells to be supplied with the UPS, and to the relevant cell temperatures referred to in (2.4).

6.2 FACTORY ACCEPTANCE TESTS

The following tests shall be performed in accordance with IEC 60146-4 The Principal shall specify in the data/requisition sheet which, if any, of the tests he will witness. The Manufacturer's standard test protocol will be acceptable provided it is no less stringent than that specified below.

6.2.1 Insulation tests

The voltages specified in the following table shall be applied for one minute to the circuits indicated:

	Control electronics < 60 V	Power electronics Un1	Auxiliary circuits Un2
	Withstand voltage		
To earth	700 V D.C.	2 x Un1 + 1000 V	2 x Un2 + 1000 V
To control electronics	-	2 x Un1 + 1000 V	2 x Un2 + 1000 V
To power electronics	2 x Un1 + 1000 V	-	2 x Un1 + 1000 V
To auxiliary circuits	2 x Un2 + 1000 V	2 x Un1 + 1000 V	-

D.C. test voltages may be applied instead of A.C. The magnitude of D.C. test voltages to be applied shall be $\sqrt{2}$ times the above mentioned A.C. (r.m.s.) values.

6.2.2 Load-duration test

All UPS units to be supplied as part of the purchase order shall be subjected to a load-

duration test performed at rated voltage and rated output current to verify the correct functional operation of the unit under full load stable operating conditions. Ambient temperature and temperatures within the unit shall be monitored and recorded for future comparison purposes.

6.2.3 Functional tests

A complete functional test shall be performed on each UPS unit. If, during the execution of functional tests, an electronic component of the UPS is required to be replaced, e.g. due to UPS malfunction or failure of the unit to fulfil the performance requirements of the specification, then the UPS load-duration test shall be repeated at rated current following which the functional tests shall be carried out.

The re-charge current limitation of the rectifier, as defined by the type of battery, shall be verified.

6.2.4 UPS unit static load tests

a) 1-phase Units

Measurements shall be carried out at zero, 50% and 100% of unit rated output current and shall be repeated for inverter D.C. input voltages corresponding to battery float-charge operation (nominal input voltage) and the rated maximum and minimum inverter input voltage.

The following shall be measured:

- input voltage;
- input current;
- DC voltage;
- DC current;
- output voltage, frequency and waveform distortion;
- output phase current(s);
- output power;
- output waveform distortion;
- determination of unit overall efficiency.

b) 3-phase Units

Measurements shall be carried out for 3 phase inverters under balanced conditions as described in a) for 1-phase using a balanced 3-phase load.

Measurements shall also be carried out under unbalanced load conditions such that the current in one phase of the inverter differs from that in the other two phases by 100% of the rated output current.

Measurements shall be carried out for inverter D.C. input voltages corresponding to battery float-charge operation (nominal voltage) and the rated maximum and minimum inverter input voltage.

The following shall be measured:

- as specified for a single phase unit, plus
- angular displacement of output phase voltages

6.2.5 UPS unit dynamic load tests

Measurements of inverter output voltage variations, in the form of oscillograms, shall be recorded in response to:

- instantaneous load changes of 100% rated output.
  Measurements shall be recorded when the load is switched to/from the inverter via the static bypass switch and via the load circuit switch
- application of a short circuit to the inverter output via a type gG or gR fuse or MCB (size as stated in the requisition), with both the bypass isolated and the unit switching to bypass to clear the fault;
- application of a 150% short time overload on the unit output.

6.2.6 Load transfer tests

Measurements shall be carried out to verify the correct functioning of the bypass circuit voltage and frequency monitoring circuit, and the inverter/bypass synchronous operating controls.

Measurements of the load voltage waveform(s), in the form of oscillograms, shall be carried out during the following load transfer tests which shall be performed with the UPS delivering full load and zero load and with the inverter operating in synchronism with the bypass circuit supply:

- load transfer to bypass initiated by manual operation of load transfer switch;
- load transfer to bypass initiated by simulating inverter malfunction;
- load transfer to bypass initiated by low DC voltage;
- load transfer to bypass initiated by loss of synchronism;
- load transfer to bypass initiated by input voltage out of tolerance;
- load transfer to bypass initiated by short circuiting of fuse protected load circuit;
- load retransfer to inverter initiated automatically and manually;
- lock-out of automatic load retransfer on sustained and recurring fault;

Variation of voltage and frequency of the bypass supply shall also be simulated to check tolerance and functionality of unsynchronised operation.

6.2.7 Auxiliary equipment and control circuit tests

The correct functioning of all measuring instruments, alarms and indications, protection and controls referred to in (4) and (6) shall be verified.

6.2.8 DC ripple measurement

The DC ripple current shall be measured at full load 0.8 power factor using a simulated battery connection.

6.2.9 Battery certification requirements

A battery certificate shall be provided stating the design capacity and the discharge volts per cell after the specified discharge time as stated in the requisition, for the battery in as-new condition.

7. DOCUMENTS

The Manufacturer shall provide technical manual(s) and drawings in accordance with the purchase order requirements, which shall include at least the following documents (preferably on a CD ROM):

- single line diagram of the unit;
- general arrangement drawings;
- main and control circuit schematic diagrams;
- equipment lists;
- recommended spare parts lists;
- test reports and performance curves, including oscillograms.
- operating manuals incorporating installation, commissioning, operating and maintenance instructions, and fault-finding procedures.

CD ROMs shall incorporate all viewer software necessary to access the information provided.

8. REFERENCES

In this DEP, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments, supplements or revisions thereto.

SHELL STANDARDS

Index to DEPs and Standard Specifications	DEP 00.00.05.05-Gen.
Requisition sheet for Static UPS Unit	DEP 33.65.50.94-Gen.

NOTE: Requisition sheets are contained in the requisitioning binder (DEP 31.10.01.10-Gen.)

BRITISH STANDARDS

Lead-acid stationary cells and batteries: Part 4: Specification for classifying valve regulated types	BS 6290-4

Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
UK.

EUROPEAN STANDARDS

Uninterruptible power systems (UPS)	EN 50091

Issued by:
CENELEC,
2 Rue Brederode
B-1000 Brussels
Belgium

Copies can also be obtained from national standards organizations

INTERNATIONAL STANDARDS

Semiconductor converters	IEC 60146
Semiconductor convertors - General requirements and line commutated convertors: Part 1-1: Specifications of basic requirements	IEC 60146-1-1
Semiconductor convertors: Part 4: Method of specifying the performance and test requirements of uninterruptible power systems	IEC 60146-4
Low-voltage fuses: Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application)	IEC 60269-2
Identification of apparatus terminals and general rules for a uniform system of terminal marking, using an alpha-numeric notation.	IEC 60445
Classification of degrees of protection provided by enclosures.	IEC 60529
Low voltage switchgear and controlgear	IEC 60947

Electromagnetic compatibility (EMC):
Part 3 : Limits.
Section 2 : Limits for harmonic current emissions (equipment input current ≤ 16 A per phase). — IEC 61000-3-2

Issued by:
Central Office of the IEC (Sales Dept.) and ISO Central Secretariat,
3, Rue de Varembé,
CH 1211 Geneva 20,
Switzerland

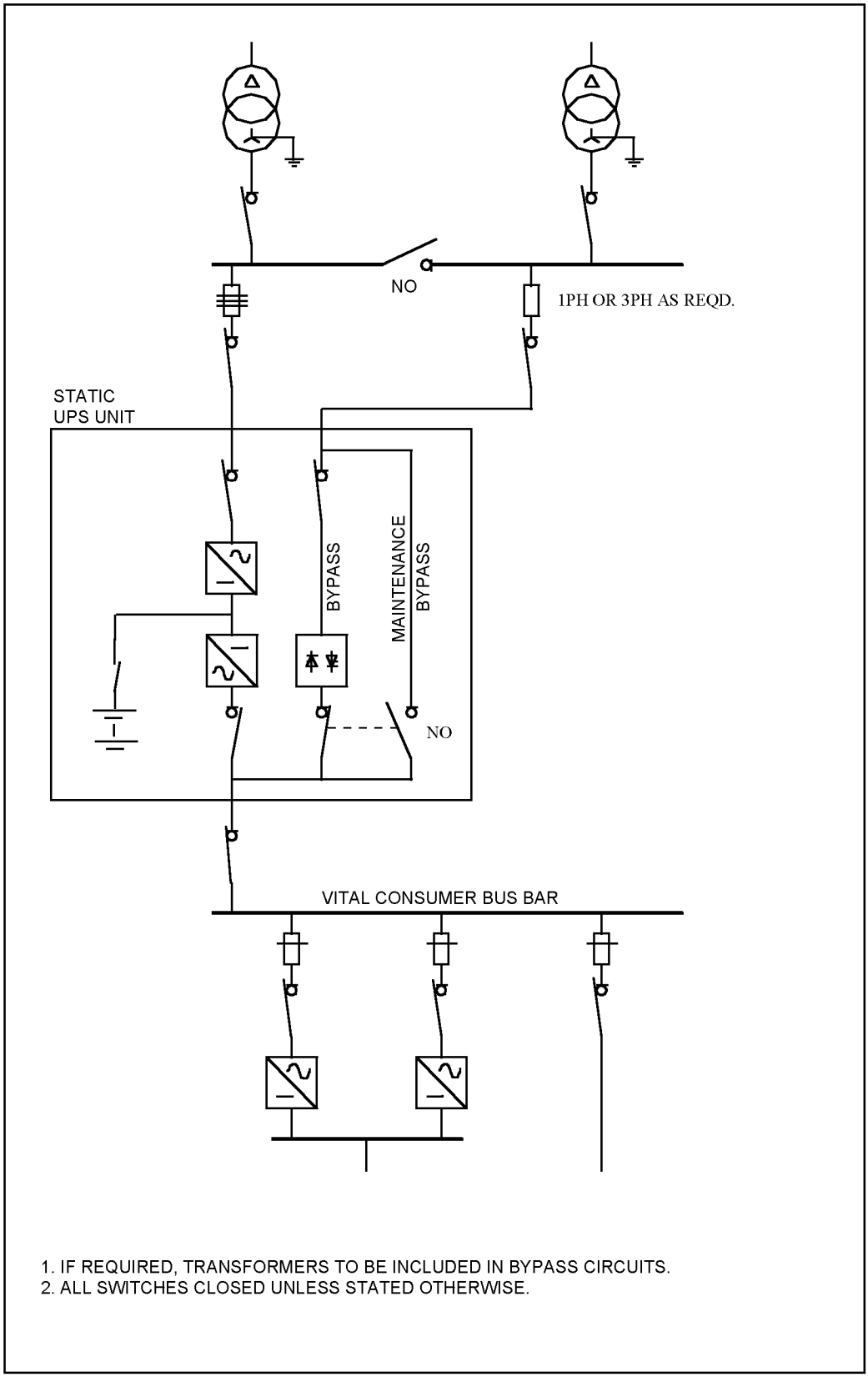
Copies can also be obtained from national standards organizations.

Acoustics - determination of sound power levels of noise sources using sound pressure. survey method using an enveloping measurement surface of a reflecting plan — ISO 3746

Issued by:
International Organisation for Standardisation
1, Rue de Varembé
CH-1211 Geneva 20
Switzerland.

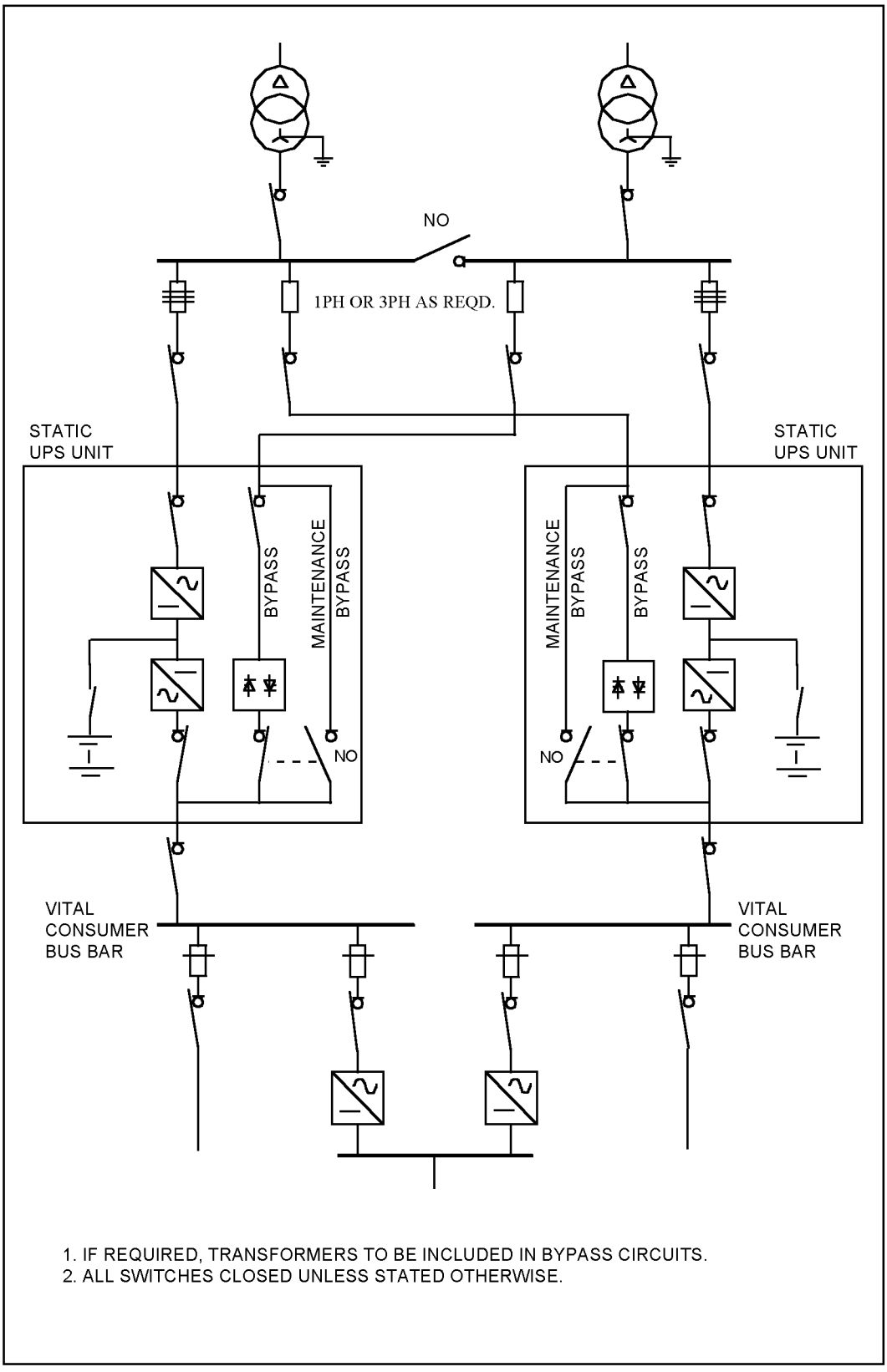
Copies can also be obtained from national standards organizations.

APPENDIX 1 TYPICAL TIE-IN OF SINGLE STATIC UPS UNIT



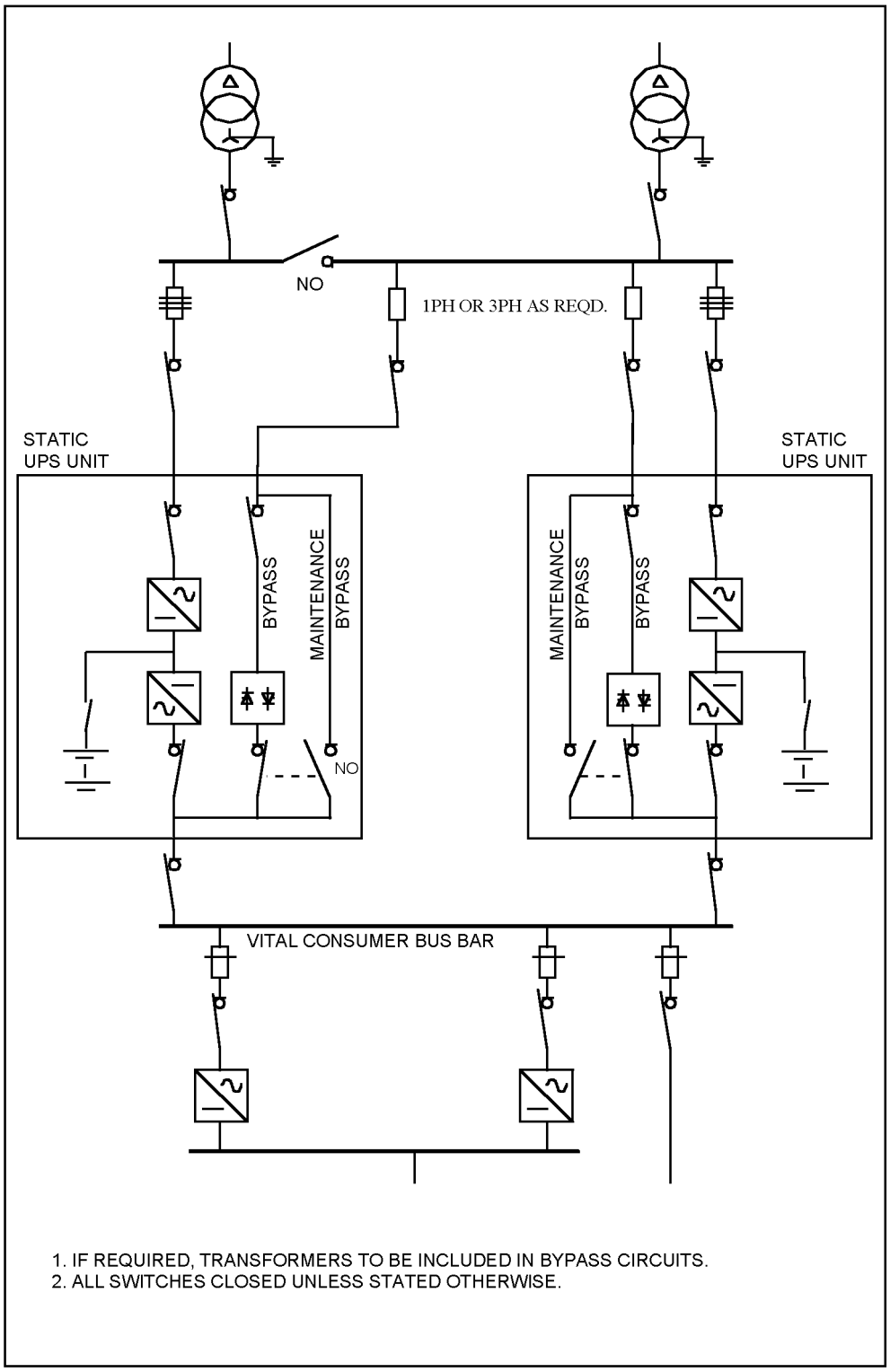
1. IF REQUIRED, TRANSFORMERS TO BE INCLUDED IN BYPASS CIRCUITS.
2. ALL SWITCHES CLOSED UNLESS STATED OTHERWISE.

APPENDIX 2 TYPICAL TIE-IN OF DUPLICATE STATIC UPS UNITS



1. IF REQUIRED, TRANSFORMERS TO BE INCLUDED IN BYPASS CIRCUITS.
2. ALL SWITCHES CLOSED UNLESS STATED OTHERWISE.

APPENDIX 3 TYPICAL TIE-IN OF DUPLICATE STATIC UPS UNITS - PARALLEL OPERATION



APPENDIX 4 SAMPLE BATTERY CALCULATION

Calculation shall be based on specifying the system rated performance at the end of the battery design life.

Design temperature for batteries shall be as specified in (2.4), unless stated otherwise in the data requisition. All batteries shall be derated in accordance with Manufacturer's recommendations.

$$DCW = \frac{VA \times pf}{\eta}$$

where DCW = Inverter Input Power

VA = System AC design load
pf = System power factor
η = Inverter efficiency, %

$$BDCW = \frac{DCW \times L}{T}$$

where BDCW = Battery power required

L = Ageing Factor (1.25 for VRLA, 1.1 for NiCd and vented lead acid)
T = Temperature derating factor

$$Vd = \frac{\text{Cable ohms} \times DCW}{V_{DCmin}}$$

where Vd = Battery cable max volt drop at I_{DCmax}

$$I_{DCmax} = \frac{DCW}{V_{DCmin}}$$

V_{DCmin} = UPS minimum DC operating voltage which will maintain the output regulation to within the limits as defined in (2.3)

$$B_{cells} = \frac{(V_{DCmin} + Vd)}{fdv}$$

where B_{cells} = Number of cells required

fdv = Final Discharge Voltage

(VRLA = 1.8 V per cell
vented lead acid = 1.7 V per cell
NiCd = 1.1 V per cell)

$$\text{BDCW per cell} = \frac{BDCW}{B_{cells}}$$

where BDCW per cell = Battery watts required per cell

The nearest upward standard cell shall be selected based on the Manufacturer's discharge tables for the endpoint voltage defined above and the specified battery autonomy time given in the requisition, taking into account the specified design temperatures and the Manufacturer's standard derating factors.