NOTE: DOD-STD-2145 has been redesignated as a Design Criteria Standard. The cover page has been changed for Administrative reasons. There are no other changes to this Document.

METRIC

DOD-STD-2145 (SH)
1 JUNE 1983

# DEPARTMENT OF DEFENSE
# DESIGN CRITERIA

# DISCONNECT SWITCH BOXES, CONTRACTOR PANELS AND SWITCHBOARDS, LOW MAGNETIC FIELD DESIGN OF (METRIC)

AMSC N/A FSC 6110

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DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND

Washington, DC 20362

Disconnect Switch Boxes, Contactor Panels and Switchboards, Low Magnetic Field Design of (Metric).

DOD-STD-2145(SH)

1. This Military Standard is approved for use by the Naval Sea Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 55Z3, Department of the Navy, Washington, DC 20362 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

# FOREWORD

1. This standard provides the designer of direct current (d.c.) disconnect switch boxes, contactor panels, switchboards, power panels and motor controllers with techniques for reducing the stray magnetic field produced by current in the conductors and devices to a minimum. This can be accomplished by arranging conductors and devices for these boxes and panels in a suitable manner. The techniques can be applied to the design of other control equipment in d.c. power circuits when the minimization of the stray magnetic field produced by the equipment is an important consideration.

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FIGURES



TABLES



APPENDIX

## 1. SCOPE

1.1 Scope. This standard covers requirements for the arrangement of conductors and devices for disconnect switch boxes and contactor panels used in d.c. circuits that will reduce the stray magnetic field to a minimum.

1.1.1 Application. The requirements of this standard are applicable to disconnect switch boxes, contactor panels, switchboards, power panels and motor controllers used in d.c. circuits aboard minesweepers and other special installations where stray magnetic fields must be reduced to a minimum. In particular, the requirements of this standard apply to disconnect switch boxes and contactor panels which may be connected in the magnetic minesweep cable run between the magnetic minesweep generator(s) and the minesweep cable terminal box. The requirements of this standard may also be applied to the design of other control equipment in d.c. power circuits.

1.1.2 Limitations. This standard shall be used in conjunction with the requirements of all technical specifications and standards for a specific disconnect switch box or contactor panel. In the event that any requirement of this standard conflicts with the requirements of other technical specifications and standards for the box or panel, the conflict shall be brought to the attention of the Naval Sea Systems Command for resolution.

## 2. REFERENCED DOCUMENTS

2.1 Issues of documents. The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this standard to the extent specified herein.

STANDARDS

MILITARY

DOD-STD-2133 - Cable Arrangement For Minimum Stray Magnetic Field (Metric).
DOD-STD-2141 - Definitions and Systems of Units, Magnetic Silencing (Metric).
DOD-STD-2143 - Magnetic Silencing Requirements for the Construction of Nonmagnetic Ships and Crafts (Metric).

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

## 3. DEFINITIONS

3.1 General magnetic silencing terms. The meanings of general magnetic silencing terms used in this standard are in accordance with DOD-STD-2141.

3.1.1 Conductors. Conductors, as used in this standard, refer to busbars and cables used in the power circuit of disconnect switch boxes and contactor panels.

3.1.2 Contactor panel. A contactor panel for use in the circuit of the magnetic minesweep cable contains contactors for repeatedly establishing and interrupting the circuit. It usually contains associated devices, such as a disconnect switch, an ammeter shunt for metering of current, and an overload relay for sensing current overloads.

3.1.3 Current loop. A current loop is a closed electric conductor. It may have one or more turns of any size or shape and may be arranged in any way. A simple current loop is a closed conductor making one turn in a single plane, or alternatively, making a number of turns which are in the same plane or in parallel planes and so close together that to a first approximation they can be considered to be physically coincident in space. More complicated current loops can be resolved into a combination of single current loops.

3.1.4 Dipole. A dipole consists of a north magnetic pole and a south magnetic pole separated by a very small distance. The axis of the dipole is along the line between the south and north magnetic poles, with the positive direction being in the direction internally from the south pole to the north pole.

3.1.5 Disconnect switch box. A disconnect switch box for use in the circuit of the magnetic minesweep cable contains a disconnect switch for opening or closing the circuit. It usually contains associated devices, such as an ammeter shunt for metering of current and an overload relay for sensing current overloads.

3.1.6 Magnetic minesweep cable. The magnetic minesweep cable is the interconnecting cable between the magnetic minesweep generator(s) and the minesweep cable terminal box.

3.1.7 Magnetic minesweep generator. A magnetic minesweep generator is a generator which produces current for a magnetic minesweeping operation.

3.1.8 Minimum magnetic moment. A minimum magnetic moment has a magnitude close to zero.

3.1.9 Motor controller. Motor controller is a device used to start and stop a motor.

3.1.10 Parallel compensation. Parallel compensation is achieved when two current loops, connected together in parallel, carry the same current and have the same size, shape and number of turns and are in the same plane with mirror image symmetry (see figure 1).

3.1.11 Power panel. A power panel is a bulkhead mounted enclosure with circuit breakers which provides control distribution and protection of selected portions of the power system.

3.1.12 Switchboard. A switchboard is a free standing enclosure which provides for control, metering and protection of the ship service generators and control distribution and protection of the power system.

3.1.13 Three-terminal device. A three-terminal device is equipment in which three terminals, one positive and two negative, or two positive and one negative, project from the device for connection to a cable run. The device (that is, disconnect switch boxes and contactor panels) may have multiple sets of three terminals for incoming and outgoing cable runs.

3.1.14 Two-terminal device. A two-terminal device is equipment in which two terminals, one positive and one negative, project from the device to a cable run.

## 4. GENERAL REQUIREMENTS

4.1 Conductor and device arrangement. Conductors for and the devices in the power circuits for disconnect switch boxes, contactor panels, switchboards, power panels and motor controllers shall be physically arranged and interconnected in a manner that will result in circuits which produce a minimum stray magnetic field.

4.2 Simplicity of conductor and device arrangement. Arrangement of conductors and devices for the power circuits shall be uncomplicated and straightforward and, at the same time, produce a minimum stray magnetic field.

4.3 Arrangement of power circuit for minimum magnetic moment and minimum magnetic moment separation. The size of current loops created by the power circuits shall be kept as small as possible to minimize the magnetic moments of the current loops. The distance between these current loops shall also be minimized. Conductor and device separation shall be kept to the minimum required by the electrical creepage and clearance distances of the applicable specification for the disconnect switch boxes, contactor panels, switchboards, power panels and motor controllers.

4.4 Arrangement of power circuit for minimum net magnetic moment. Current loops created by the power circuits shall be arranged such that the resultant or net magnetic moment will be minimized.

4.4.1 Utilization of parallel compensation in the arrangement of power circuits. Parallel compensation shall be utilized in the arrangement of power circuits in order to assist in achieving a minimum net magnetic moment. Electrical resistance of parallel conductors shall be equalized, as required by a particular circuit arrangement, so that maximum parallel compensation is achieved.

4.5 External cable connections to disconnect switch boxes and contactor panels. External cable connections shall be made in accordance with DOD-STD-2133.

4.6 Material. Material used in the construction of disconnect switchboxes, contactor panels, switchboards, power panels and motor controllers shall conform to the material requirements of DOD-STD-2143.

5. DETAILED REQUIREMENTS

5.1 Basic conductor arrangement. The basic arrangement of conductors in disconnect switch boxes, contactor panels, switchboards, power panels and motor controllers shall be a central conductor carrying two units of current in one direction sandwiched between two symmetrically placed conductors each carrying one unit of current in the opposite direction, as illustrated on figure 2. The basic conductor arrangement is compatible with the three-terminal arrangements for magnetic minesweep quad cable runs in accordance with DOD-STD-2133. Consequently, disconnect switch boxes and contactor panels with this basic conductor arrangement are three-terminal devices.

5.2 Conductor bends. Conductor bends can be one of two types: (a) the conductors lie in different planes on each side of the bend or (b) the conductors lie in the same plane on each side of the bend.

5.2.1 Conductors lying in different planes on each side of the bend. Bending of conductors shall be accomplished as illustrated on figure 3 when the conductors lie in different planes on each side of the bend. This arrangement will result in zero net magnetic moment of current when the currents in the two outside conductors are equal.

5.2.2 Conductors lying in the same plane on each side of the bend. Bending of conductors shall be accomplished as illustrated on figure 4 when the conductors lie in the same plane on each side of the bend. This arrangement will result in zero net magnetic moment of current when the currents in the two outside conductors are equal. This arrangement is difficult to accomplish in practice. Consequently, the preferred power circuit arrangements for disconnect switch boxes and contactor panels (see 5.4.2) utilizes conductor bends lying in different planes on each side of the bend.

5.3 Devices in power circuits. Devices in power circuits are usually series connected devices, such as ammeter shunts and overload relays. These devices are two-terminal devices and can be connected directly into the circuit or first converted to a three-terminal device and then connected into the circuit.

5.3.1 Direct connection of devices into the circuit. Direct connection of devices into the circuit shall be accomplished by inserting the device into the circuit of the central conductor on figure 2. The two outer conductors shall be spread symmetrically around each side of the device.

5.3.2 Conversion to a three-terminal device. If a two-terminal device is placed in a three-terminal box, it shall be connected into the circuit as illustrated on figure 5.

5.4 Power circuit arrangements. Power circuit arrangements shall be of the folded or crisscross type. The straight-through type of arrangement shall not be used.

5.4.1 Straight-through arrangement. The straight-through arrangement, as illustrated on figure 6 for a disconnect switch box, shall not be used since the creation of a low stray magnetic field with this design is very dependent upon equal current division between the two outer conductors.

5.4.2 Folded arrangement. The folded arrangement, as illustrated on figure 7 for disconnect switch boxes and figure 8 for contactor panels, shall be the preferred arrangement. This arrangement shall be used in all cases except where special circumstances make it indispensable or highly advantageous to have a disconnect switch box or contactor panel with incoming and outgoing terminals at opposite ends of the box or panel. The folded arrangement inherently requires the incoming and outgoing terminals to be at the same end of the box or panel. Actual separation of conductors shall be the minimum required to meet the applicable electrical creepage and clearance distances specified for the disconnect switch box.

Preparing activity:
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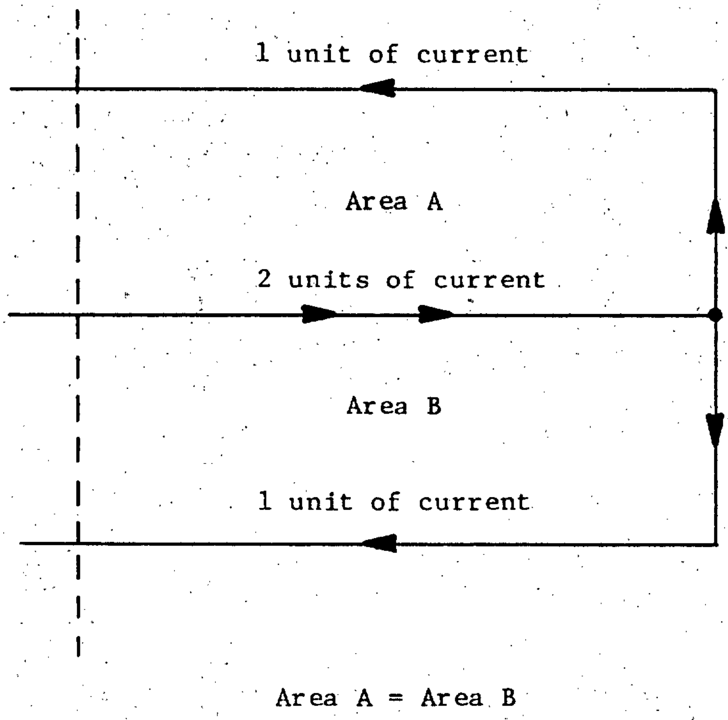
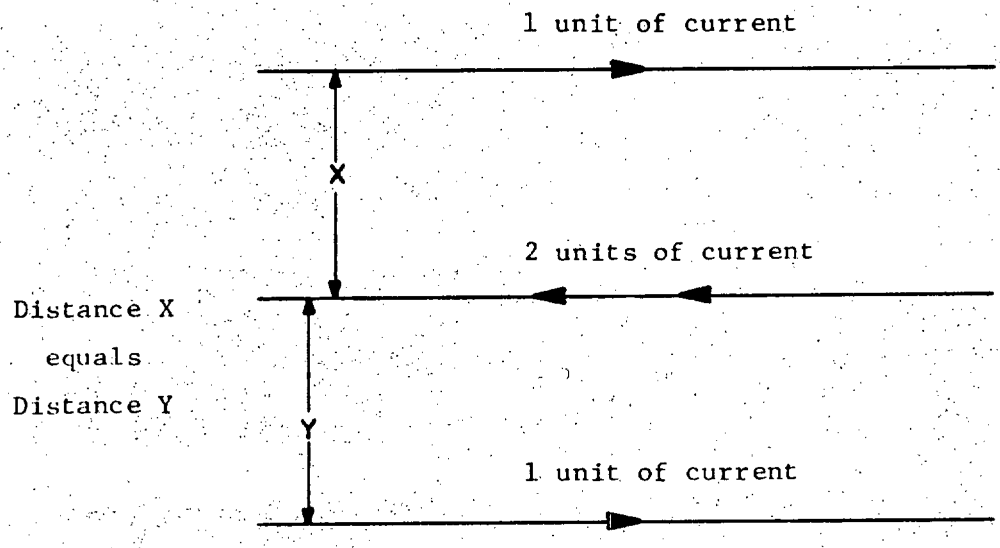
(Project 6110-N239)




SH 12228

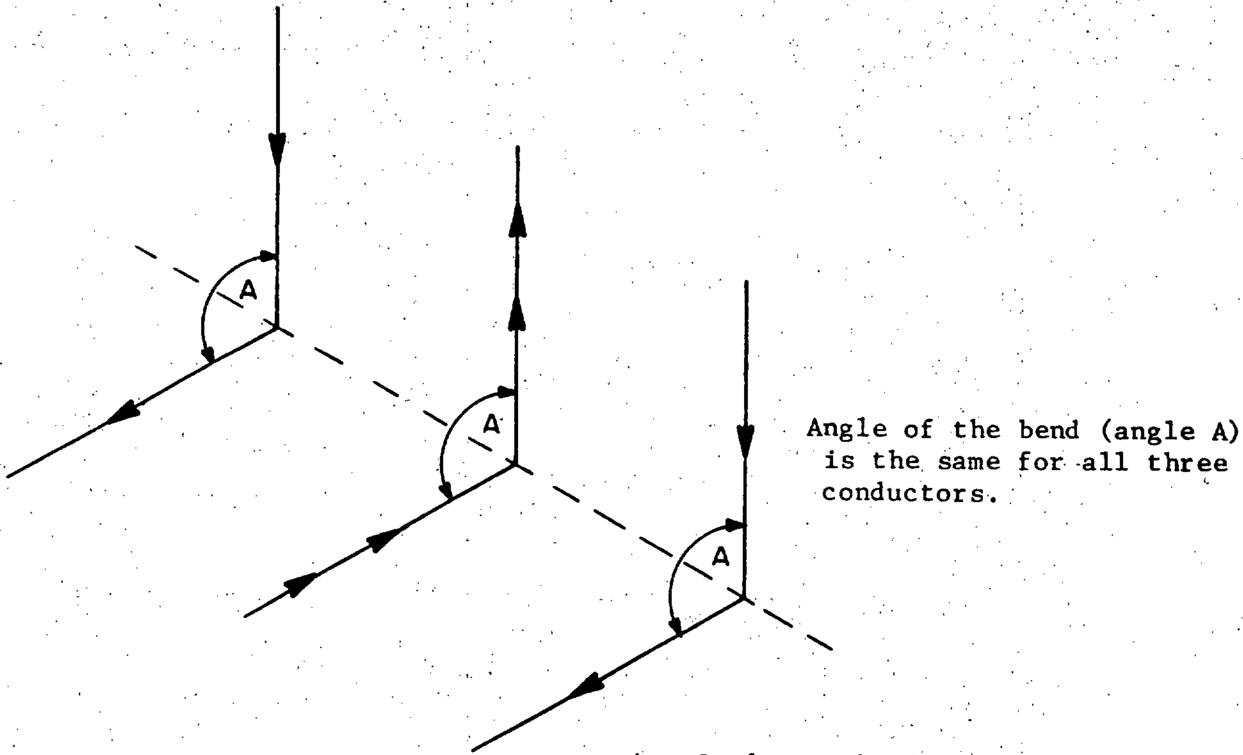
FIGURE 1. Parallel compensation.



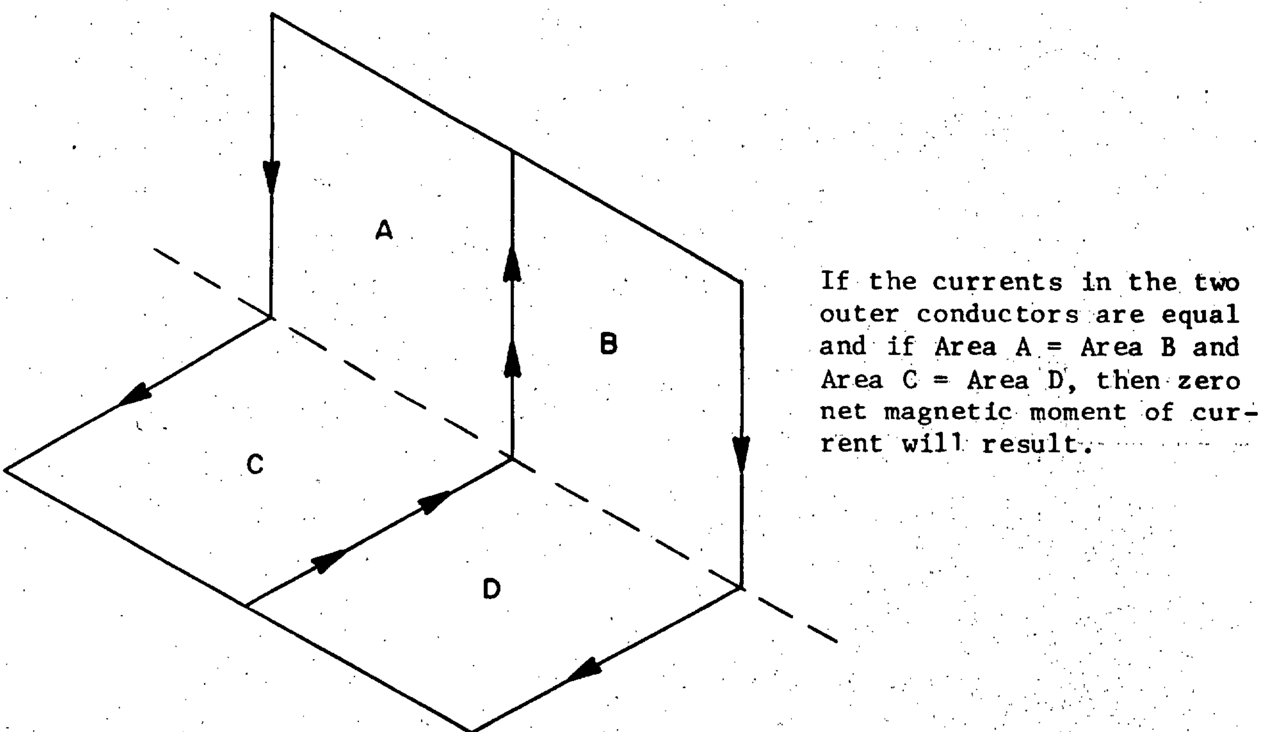

NOTE: In all figures, quantity of arrows indicates relative magnitude of current. The direction of the arrows indicates direction of current.

SH 12229

FIGURE 2. Basic arrangement of conductors in disconnect switch boxes and contactor panels.



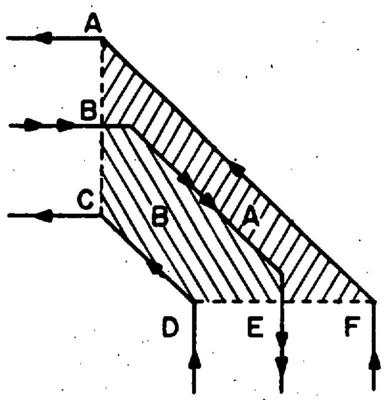

A. Conductor bend in two planes.




B. Resulting current loops.

SH 12230

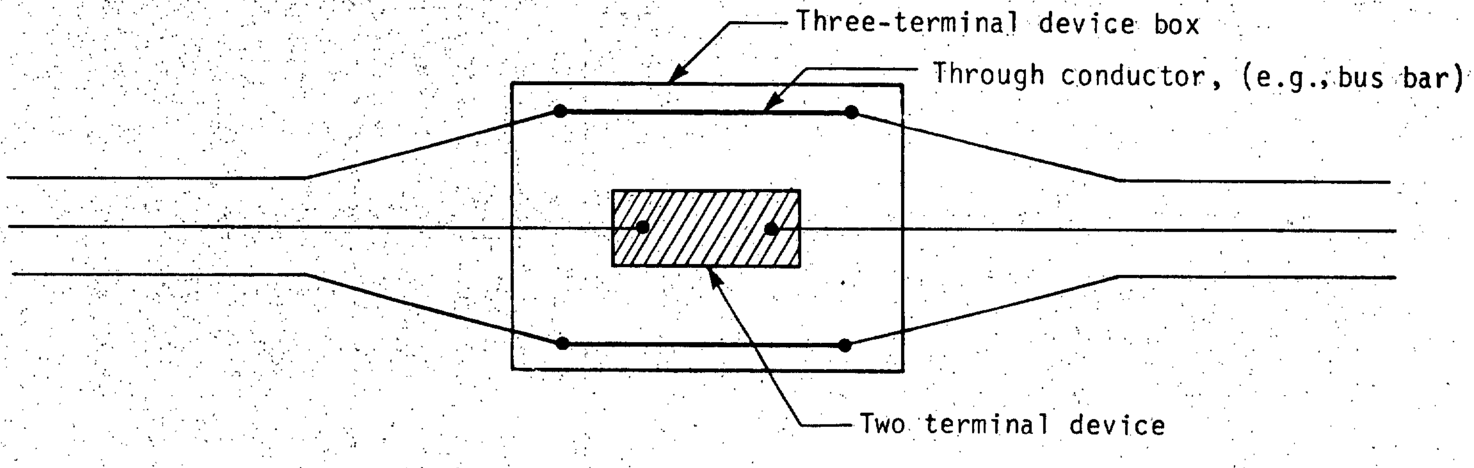
FIGURE 3. Bend for conductors lying in different planes on each side of the bend.



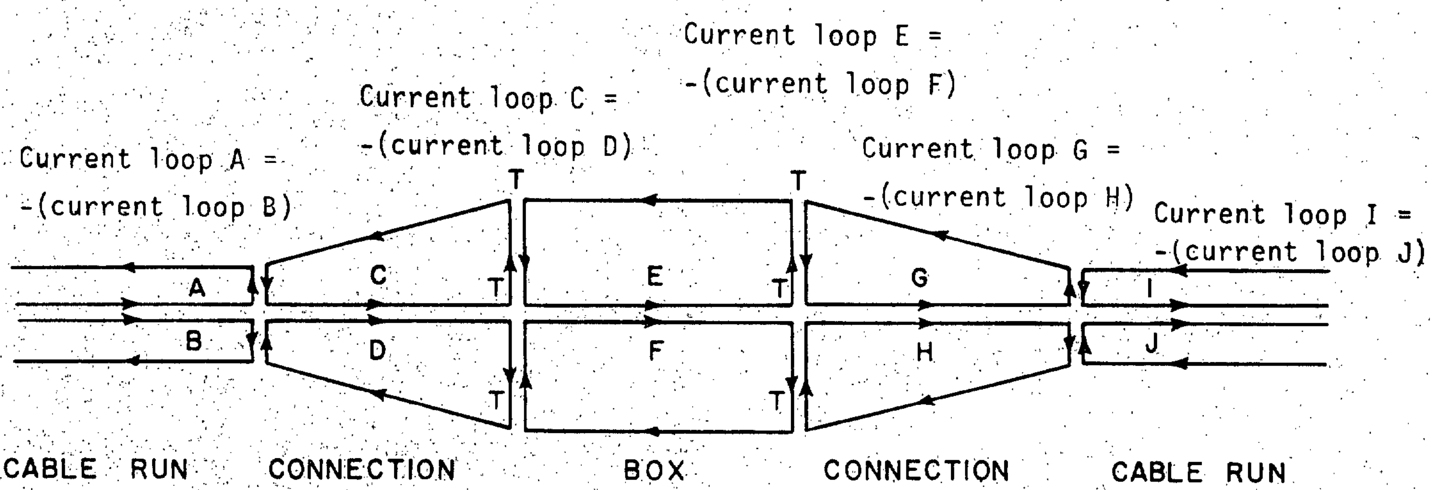

If the currents in the two outer conductors are equal and if Area A = Area B, then there is zero net magnetic moment of current.

SH 12231

FIGURE 4. Bend for conductors lying in the same plane on each side of the bend.



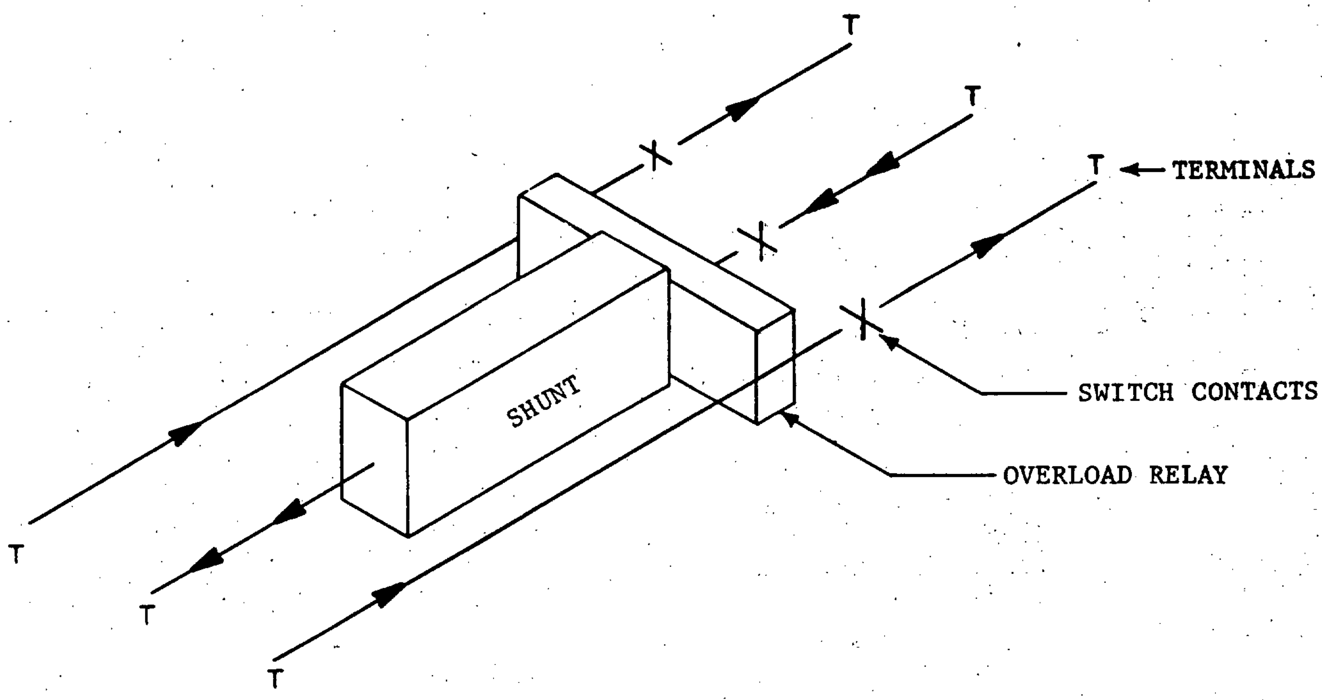

A. Circuit for a two-terminal device in a three-terminal box.




B. Resulting current loops for circuit in A.

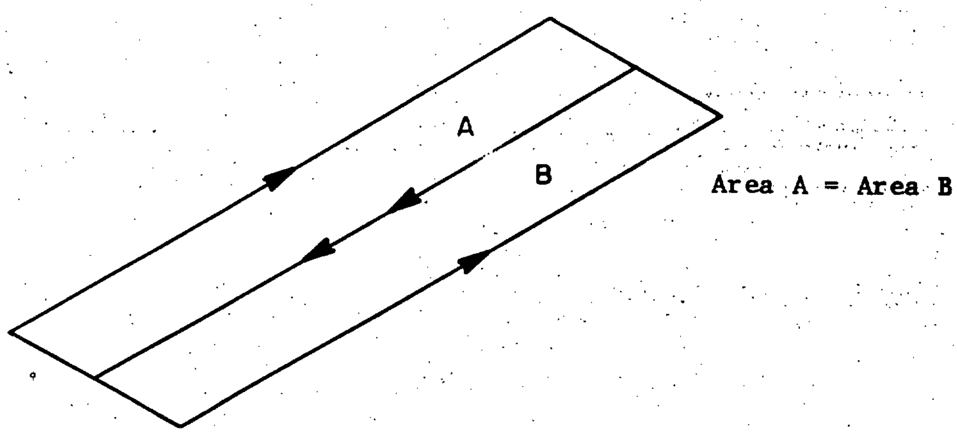
SH 12232

FIGURE 5. Conversion of a two-terminal device to a three-terminal device and resulting current loops.




A. Circuit for disconnect switch box with a straight-through conductor arrangement.

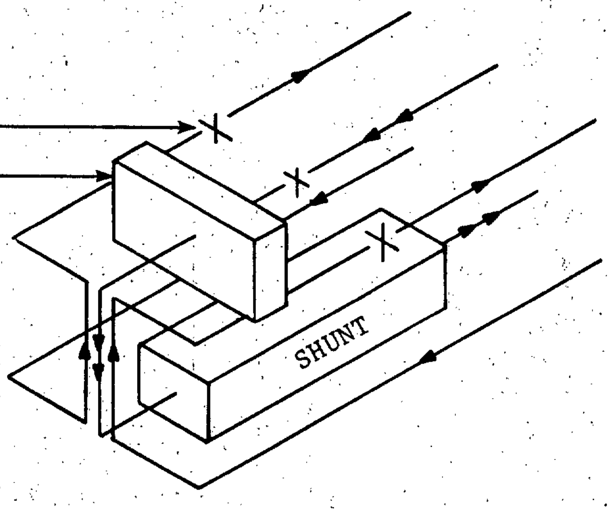
Zero net magnetic moment is not achieved unless the current in the two outer loops are exactly equal to each other.




B. Resulting current loops for circuit in A.

SH 12233

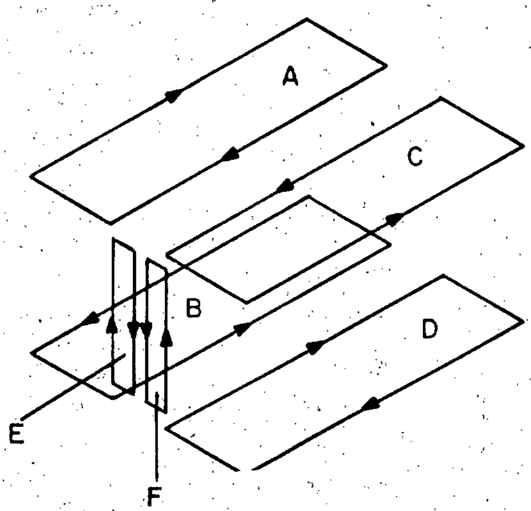
FIGURE 6. Straight-through arrangement (not to be used) for a disconnect switch box.




A. Circuit for disconnect switch box with a folded arrangement.

Area A = Area B = Area C = Area D

Area E = Area F

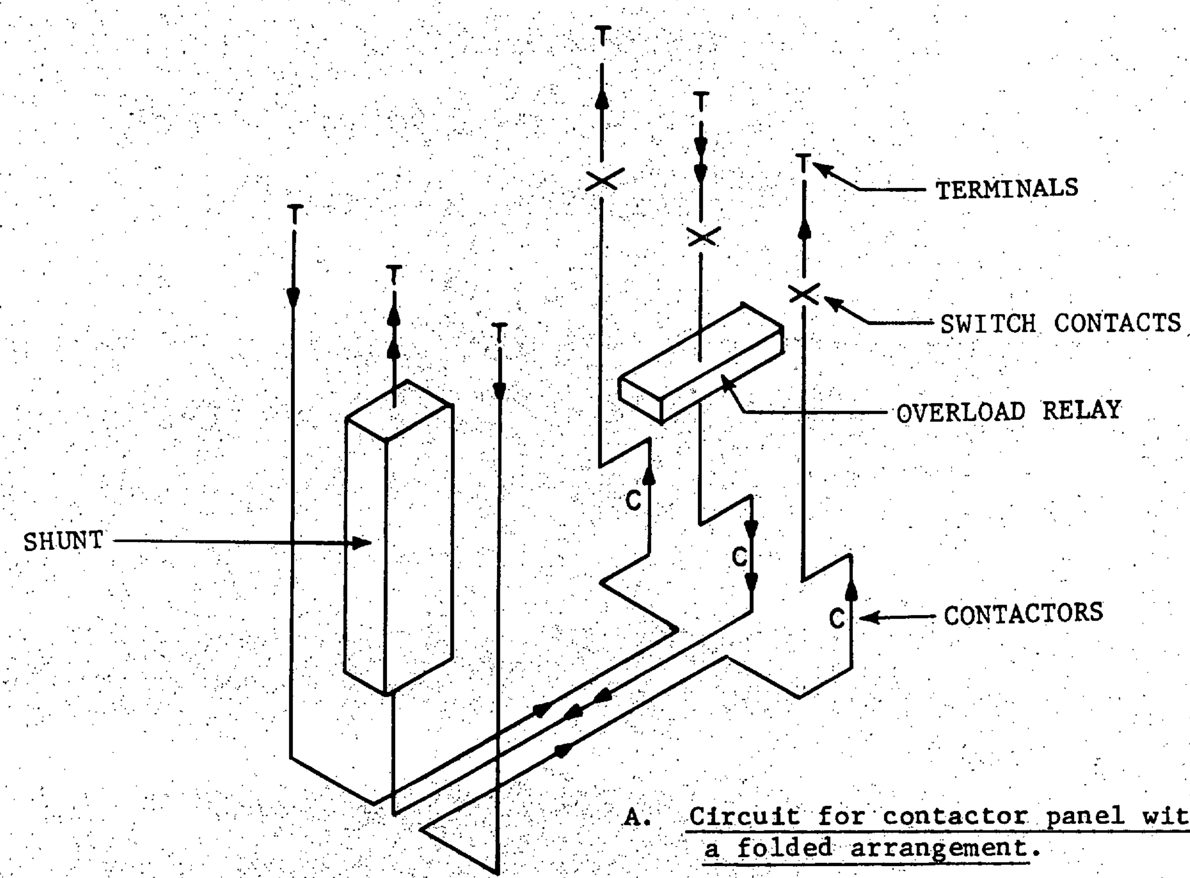



Net magnetic moment for loops A, B, C and D is equal to zero regardless of equal current division between the two outer conductors. Loops E and F will not be balanced in the case of unequal current division; consequently, loops E and F shall be as made as small as possible.

B. Resulting current loops for circuit in A.

SH 12234

FIGURE 7. Folded arrangement for a disconnect switch box.

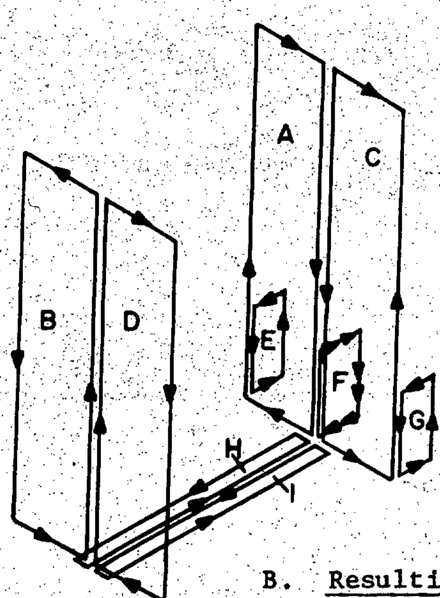



A. Circuit for contactor panel with a folded arrangement.

Area A = Area B = Area C = Area D

Area E = Area F = Area G

Area H = Area I




Net magnetic moment for loops A, B, C and D is equal to zero regardless of equal current division between the two outer conductors; similarly for current loops E, F and G. Loops H and I will not be balanced in the case of unequal current division; consequently loops H and I shall be made as small as possible.

B. Resulting current loops for circuit in A.

SH 12235

FIGURE 8. Folded arrangement for a contactor panel.

# APPENDIX

## COMPARISON OF EFFECTIVENESS OF FOLDED AND CRISSCROSS ARRANGEMENTS FOR DISCONNECT SWITCH BOXES

### 10. GENERAL

10.1 Scope. This appendix illustrates the comparative effectiveness of folded and crisscross arrangements for disconnect switch boxes.

### 20. REFERENCED DOCUMENTS

Not applicable.

### 30. DEFINITIONS

Not applicable.

### 40. GENERAL REQUIREMENTS

Not applicable.

### 50. DETAILED REQUIREMENTS

50.1 Compared arrangements. Figure 9 illustrates the folded and crisscross arrangements that are compared to the stray magnetic field they create. The dimensions are arbitrarily chosen. In all cases, the total current is taken to be 1000 amperes (A). The current loops are shown as rectangular in shape (or very nearly rectangular) and the areas are figured as if they were rectangular. In the crisscross arrangement, the four current loops in the crisscross (loops E to H on figure 10) have been omitted since these can be made so small in area that their magnetic field should be negligible.

50.2 Comparison for equal current division between outer conductors. For current equally divided between the two outer conductors (that is, each outer conductor carries 500 A while the center conductor carries 1,000 A), the maximum values of the vertical component of the magnetic field in a plane 6 meters below the centers of the two arrangements are as indicated in table I.

TABLE I. Equal division of current (500 amperes in each outer conductor).

| Arrangement type | Flux density, nanotesla (nT) |
|---|---|
| Folded | 60 |
| Crisscross | 1220 |

50.3 Comparison for unequal current division between outer conductors. For current unequally divided between the two outer conductors (that is, one outer conductor carries 600 A and the other 400 A while the center conductor carries 1,000 A), the maximum values of the vertical component of the magnetic field in a plane 6 meters below the centers of the two arrangements are as indicated in table II.

TABLE II. Unequal division of current (600 amperes in one outer conductor and 400 amperes in the other outer conductor).

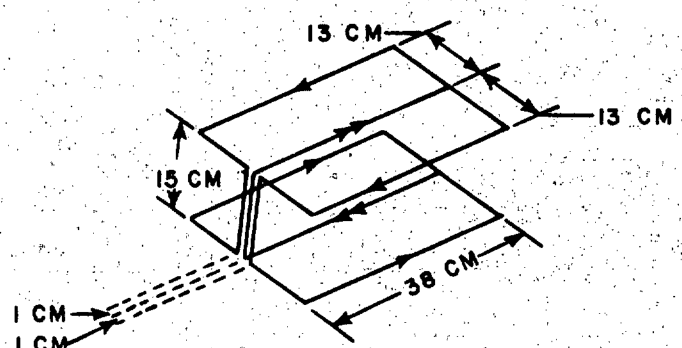
| Arrangement type | Flux density (nT) |
|---|---|
| Folded | 700 |
| Crisscross | 1300 |

50.4 Comparison for zero current in one outer conductor and 1,000 A in the other outer conductor. For the extreme case of current inequality which would arise if an open circuit developed so that one of the two outer conductors carries 1,000 A and the other carries none, the maximum values of the vertical component of the magnetic field in a plane 6 meters below the centers of the two arrangements are as indicated in table III.

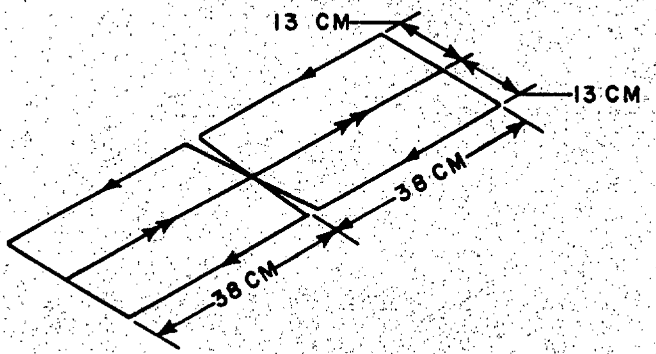
TABLE III. Zero current in one outer conductor and 1,000 amperes in the other outer conductor.

| Arrangement type | Flux density (nT) |
|---|---|
| Folded | 3000 |
| Crisscross | 4000 |

50.5 Conclusions. It is apparent from tables I, II, and III that the stray magnetic field of the folded arrangement, which is the preferred arrangement, has the smaller stray magnetic field for all conditions.



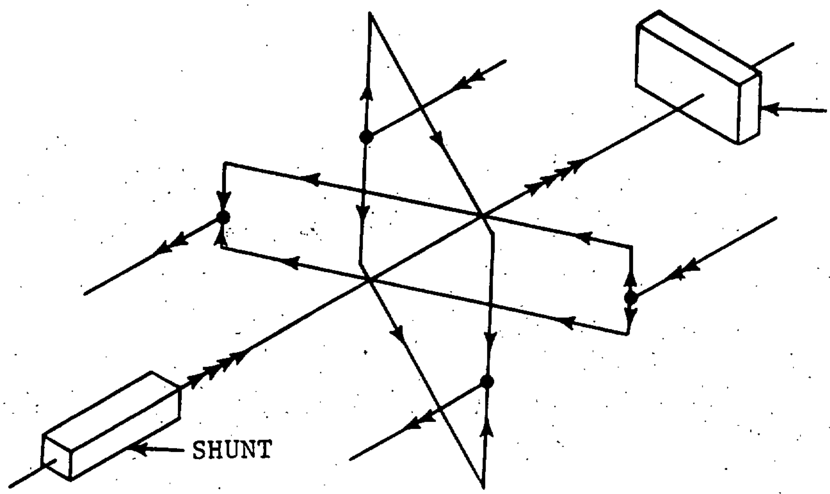

A. Folded arrangement.



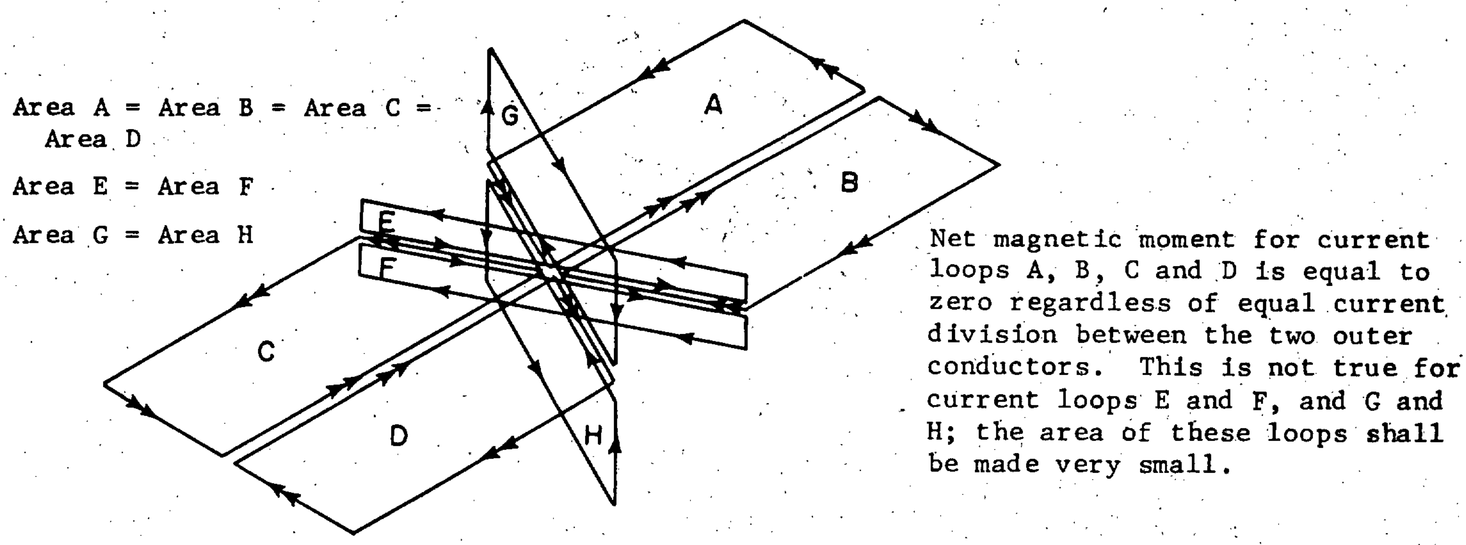

B. Crisscross arrangement.

SH 12236

FIGURE 9. Comparable folded and crisscross arrangements.




A. Partial circuit for disconnect switch box with a crisscross conductor arrangement.




B. Resulting current loops for circuit in A.

SH 12237

FIGURE 10. Crisscross arrangement for a disconnect switch box.

# STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

*(See Instructions – Reverse Side)*

| 1. DOCUMENT NUMBER | 2. DOCUMENT TITLE |
|---|---|
| DOD-STD-2145(SH) | |

**3a. NAME OF SUBMITTING ORGANIZATION**

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