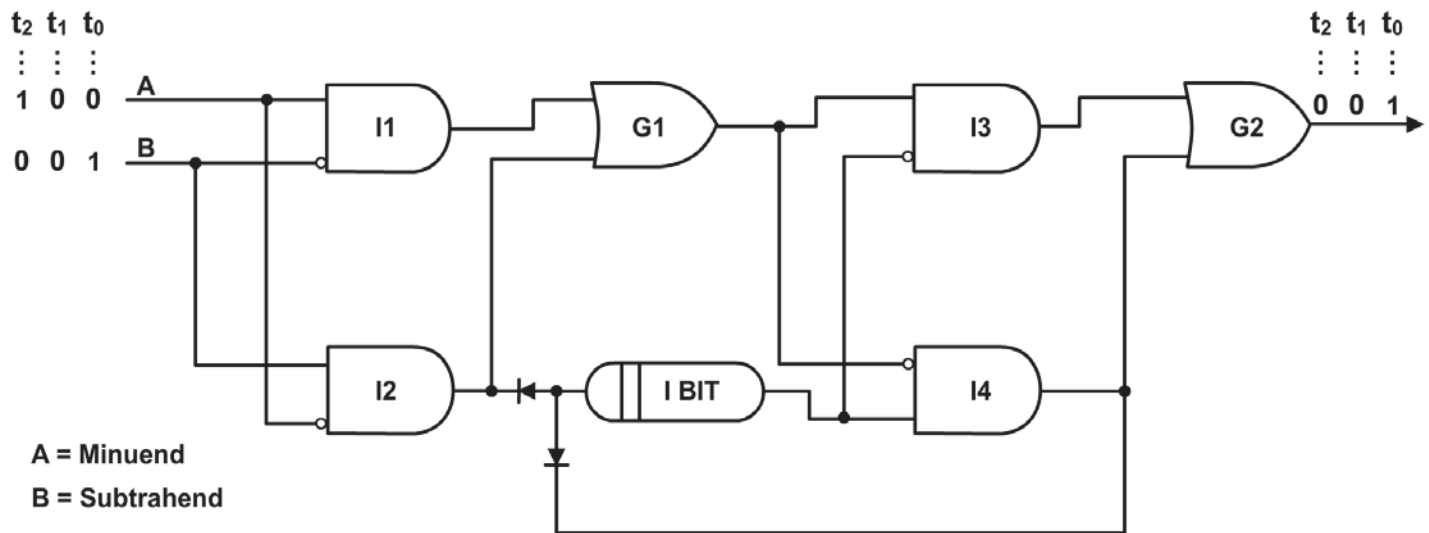


| Function     | Switching Circuit | Truth Table                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Block Diagram    |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
|--------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-----------------------|------------|------------------|-------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|------------|------------|-----------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|------|
| and          |                   | <table><tr><th>A</th><th>B</th><th>AB</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | A                | B                     | AB         | 0                | 0                 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| A            | B                 | AB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 0                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 1                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 0                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 1                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| or           |                   | <table><tr><th>A</th><th>B</th><th>A + B</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | A                | B                     | A + B      | 0                | 0                 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| A            | B                 | A + B                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 0                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 1                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 0                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 1                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| Not          |                   | <table><tr><th>A</th><th><math>\bar{A}</math></th></tr><tr><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td></tr></table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | A                | $\bar{A}$             | 1          | 0                | 0                 | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| A            | $\bar{A}$         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 0                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 1                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| Nor          |                   | <table><tr><th>A</th><th>B</th><th>A+B</th><th><math>\overline{A+B}</math></th></tr><tr><td>0</td><td>0</td><td>0</td><td>1</td></tr><tr><td>0</td><td>1</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td><td>0</td></tr></table>                                                                                                                                                                                                                                                                                                                                                                                                                                                      | A                | B                     | A+B        | $\overline{A+B}$ | 0                 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| A            | B                 | A+B                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | $\overline{A+B}$ |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 0                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 1                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0                |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 0                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0                |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 1                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0                |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| Nand         |                   | <table><tr><th>A</th><th>B</th><th>AB</th><th><math>\overline{AB}</math></th></tr><tr><td>0</td><td>0</td><td>0</td><td>1</td></tr><tr><td>0</td><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td><td>0</td></tr></table>                                                                                                                                                                                                                                                                                                                                                                                                                                                        | A                | B                     | AB         | $\overline{AB}$  | 0                 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| A            | B                 | AB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | $\overline{AB}$  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 0                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 1                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 0                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 1                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0                |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| Inhibit      |                   | <table><tr><th>A</th><th>B</th><th><math>A\bar{B}</math></th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr></table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | A                | B                     | $A\bar{B}$ | 0                | 0                 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| A            | B                 | $A\bar{B}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 0                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 1                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 0                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 1                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |                       |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| Exclusive or |                   | <table><tr><th>A</th><th>B</th><th>A+B</th><th>AB</th><th><math>(A+B)(\bar{AB})</math></th></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td></tr></table><br><table><tr><th>A</th><th>B</th><th><math>A\bar{B}</math></th><th><math>\bar{A}B</math></th><th><math>A\bar{B} + \bar{A}B</math></th></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td></tr></table> | A                | B                     | A+B        | AB               | $(A+B)(\bar{AB})$ | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | A | B | $A\bar{B}$ | $\bar{A}B$ | $A\bar{B} + \bar{A}B$ | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | <br> |
| A            | B                 | A+B                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | AB               | $(A+B)(\bar{AB})$     |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 0                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0                | 0                     |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 1                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0                | 1                     |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 0                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0                | 1                     |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 1                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                | 0                     |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| A            | B                 | $A\bar{B}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | $\bar{A}B$       | $A\bar{B} + \bar{A}B$ |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 0                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0                | 0                     |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 0            | 1                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                | 1                     |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 0                 | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0                | 1                     |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |
| 1            | 1                 | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0                | 0                     |            |                  |                   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |            |            |                       |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |      |

Figure 6-19 — Logic operations comparison chart.

## Basic Logic Diagrams

Basic logic diagrams are used to show the operation of a particular unit or component. Basic logic symbols are shown in their proper relationship so as to show operation only in the most simplified form possible. A basic logic diagram for a serial subtractor is illustrated in *Figure 6-20*. The operation of the unit is described briefly in the next paragraph.



**Figure 6-20 — Serial subtractor, basic logic diagrams.**

As an example, in the basic subtractor, subtract binary 011 (decimal 1) from binary 100 (decimal 4).

At time  $t_0$ , the 0 input at A and 1 input at B of inhibitor I1 results in a 0 output from inhibitor I1 and a 1 output from inhibitor I2. The 0 output from I1 and the 1 output from I2 are applied to OR gate G1, producing a 1 output from G1. The 1 output from I2 is also applied to the delay line. The 1 output from G1 along with the 0 output from the delay line produces 1 output from I3. The 1 input from G1 and the 0 input from the delay line produce a 0 output from inhibitor I4. The 0 output from I4 and the 1 output from I3 are applied to OR gate G2 producing a 1 output.

At time  $t_1$  the 0 inputs on the A and B input lines of I1 produce 0 outputs from I1 and I2. The 0 inputs on both input lines of OR gate G1 result in a 0 output from G1. The 1 input applied to the delay line at time  $t_0$  emerges (1 bit time delay) and is now applied to the inhibit line of I3 producing an 0 output from I3. The 1 output from the delay line is also applied to inhibitor I4, and along with the 0 output from G1 produces a 1 output from I4. The I4 output is recycled back into the delay line, and also applied to OR gate G2. As a result of the 0 and 1 inputs from I3, and I4, the OR gate G2 produces a 1 output.

At time  $t_2$ , the 1 input on the A line and the 0 input on the B line of I1 produce a 1 output from I1 and a 0 output from I2. These outputs applied to OR gate G1 produce a 1 output from G1, which is applied to I3 and I4. The delay line now produces a 1 output (recycled in at time  $t_1$ ), which is applied to I3 and I4. The 1 output from the delay line along with the 1 output from G1 produces a 0 output from I3. The 1 output from G1 along with the 1 output from the delay line produces a 0 output from I4. With 0 outputs from I3 and I4, OR gate G2 produces a 0 output.

## Detailed Logic Diagrams

Detailed logic diagrams show all logic functions of the equipment concerned (*Figure 6-21*). In addition, they also include such information as socket locations, pin numbers, and test points to help

in troubleshooting. The detailed logic diagram for a complete unit may consist of many separate sheets.

All input lines shown on each sheet of a detailed logic diagram are tagged to show the origin of the inputs. Likewise, all output lines are tagged to show destination. In addition, each logic function shown on the sheet is tagged to identify the function hardware and to show function location both on the diagram and within the equipment.

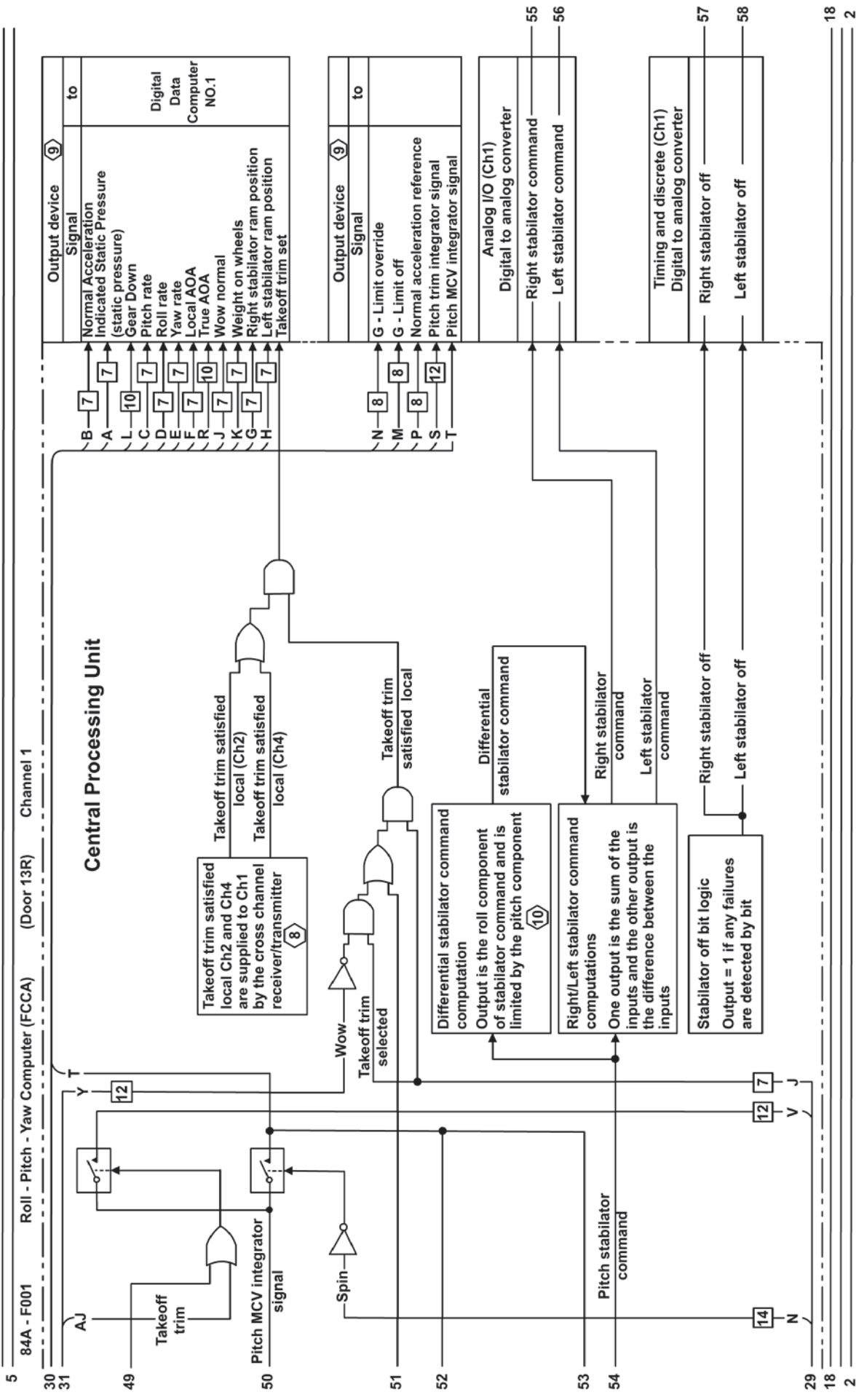


Figure 6-21 — Sample detailed logic diagram.

## End of Chapter 6

### Electrical and Electronics Prints

#### Review Questions

- 6-1. What type of diagram shows a picture or sketch of various components of a specific system?
- A. Isometric
  - B. Pictorial
  - C. Schematic
  - D. Wiring
- 6-2. What type of diagram is used to locate a component within a system?
- A. Isometric
  - B. Pictorial
  - C. Schematic
  - D. Wiring
- 6-3. What type of diagram uses symbols to represent components in a circuit?
- A. Isometric
  - B. Pictorial
  - C. Schematic
  - D. Wiring
- 6-4. What type of diagram is a detailed diagram of each circuit installation showing all connectors, terminal boards, and electrical components of a circuit?
- A. Isometric
  - B. Pictorial
  - C. Schematic
  - D. Wiring
- 6-5. The new electrical cable tag system consists of how many parts?
- A. One
  - B. Two
  - C. Three
  - D. Four
- 6-6. What type of diagram is supplied for each shipboard electrical system?
- A. Electrical troubleshooting
  - B. Ground fault isolation
  - C. Isometric deck plan
  - D. Isometric wiring

- 6-7. What type of print is used by the shipyard electrician to lay out the work for a number of cables without referring to individual isometric wiring diagrams?
- A. Block
  - B. Connection
  - C. Deck plan
  - D. Pictorial
- 6-8. What type of diagram is a valuable troubleshooting tool?
- A. Block
  - B. Connection
  - C. Deck plan
  - D. Pictorial
- 6-9. Aircraft graphic symbols are drawn according to what standard?
- A. Institute of Electrical and Electronic Engineers Standard 315A
  - B. Institute of Electrical and Electronic Engineers Standard 513A
  - C. Military Specification: Wiring, Aerospace Vehicle, SAE-AS50441
  - D. Military Specification: Wiring, Aerospace Vehicle, SAE-AS58551
- 6-10. Aircraft electrical wiring diagrams show what type of information on all electrical systems?
- A. Basic
  - B. Detailed
  - C. Sequential
  - D. Troubleshooting
- 6-11. Aircraft wire and cable identification is a combination of what two markings?
- A. Letters and numbers
  - B. Symbols and letters
  - C. Numbers and symbols
  - D. Symbols and classification label
- 6-12. In aircraft wiring identification, what letters are not used?
- A. I and L
  - B. I and O
  - C. O and Q
  - D. P and O
- 6-13. Shipboard electronic prints include what types of drawings?
- A. Advanced and basic
  - B. Elementary and advanced
  - C. Isometric and advanced
  - D. Isometric and elementary

- 6-14. A reference designation is a combination of letters and numbers used to identify the various parts and components on electronic drawings, diagrams, and what other item?
- A. Parts list
  - B. Parts catalog
  - C. Wiring schedule
  - D. Electrical installation guide
- 6-15. Aircraft electronic wiring diagrams fall into what two basic classes?
- A. Basic and advanced
  - B. Block and interconnecting
  - C. Wiring and block
  - D. Wiring and interconnecting
- 6-16. Computers operate entirely on the principle of logic using what two conditions to make a programmed decision?
- A. Logic and reason
  - B. No and prohibit
  - C. True and false
  - D. Yes and or
- 6-17. The symbolic logic operations used in computers are based on what algebraic system?
- A. Algorithm
  - B. Boolean
  - C. Monomial
  - D. Permutation
- 6-18. Logic operations consist of AND, OR, and what other basic operation?
- A. IF
  - B. IS
  - C. NOT
  - D. THEN

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# CHAPTER 7

## ARCHITECTURAL AND STRUCTURAL STEEL DRAWINGS

Architectural and structural steel drawings are generally considered to be the drawings of steel, wood, concrete, and other materials used to construct buildings, ships, planes, bridges, towers, tanks, and so on. This chapter discusses the common architectural and structural shapes and symbols commonly used for architectural and structural steel drawings, and describe the common types of drawings used in the fabrication and erection of steel structures.

### LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Recognize the elements of architectural drawings.
2. Identify various types of architectural symbols.
3. Recognize the elements of structural steel drawings.
4. Identify various types of structural symbols.
5. Identify various types of construction drawings.

A building project may be broadly divided into two major phases, the design phase and the construction phase. First, the architect conceives the building, ship, or aircraft in his or her mind, and then sets down the concept on paper in the form of presentation drawings, which are usually drawn in perspective by using pictorial drawing techniques.

The architect and engineer work together to decide upon materials and construction methods. The engineer determines the loads the supporting structural members will carry and the strength each member must have to bear the loads. He or she also designs the mechanical systems of the structure, such as heating, lighting, and plumbing systems. The end result is the preparation of architectural and engineering design sketches that will aid in preparing the construction drawings. These construction drawings, plus the specifications, are the chief sources of information for the supervisors and craftsmen who carry out the construction.

### STRUCTURAL SHAPES AND MEMBERS

Various structural members are used to manufacture a wide variety of cross section shapes and sizes. Many of the shapes are shown in *Figure 7-1*. These symbols are compiled from part 4 of Military Standard 18B (MIL-STD-18B) and information from the American Society of Construction Engineers (ASCE). The following paragraphs will explain the common structural shapes used in building materials and the common structural members that are made in those shapes.

#### Shapes

The three most common types of structural members are the W-shape (wide flange), the S-shape (American Standard I-beam), and the C-shape (American Standard channel). These three types are identified by the nominal depth, in inches, along the web and the weight per foot of length, in pounds. As an example, a W 12 x 27 indicates a W-shape (wide flange) with a web 12 inches deep and a weight of 27 pounds per linear foot.

The cross-sectional views of the W-, S-, and C-shapes are illustrated in *Figure 7-2*. The difference between the W-shape and the S-shape is in the design of the inner surfaces of the flange. The W-

shape has parallel inner and outer flange surfaces with a constant thickness, while the S-shape has a slope of approximately 17 degrees on the inner flange surfaces. The C-shape is similar to the S-shape in that its inner flange surface is also sloped approximately 17 degrees.

| OLD SYMBOL                                                                           | OLD ILLUSTRATED USE                                                                                     | DESCRIPTION                                    | EXAMPLE                                                                               | NEW SYMBOL                                                                            | NEW ILLUSTRATED USE                              |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|------------------------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|--------------------------------------------------|
| WF                                                                                   | 24 WF 76                                                                                                | W-SHAPE (WIDE FLANGE)                          |    | W                                                                                     | W 24 x 76                                        |
| BP                                                                                   | 14 BP 73                                                                                                | BEARING PILE                                   |    | HP                                                                                    | HP 14 x 73                                       |
| I                                                                                    | 15 I 42.9                                                                                               | S-SHAPE (AMERICAN STD I-BEAM)                  |    | S                                                                                     | S 15 x 42.9                                      |
|     | 9  13.4                | C-SHAPE (AMERICAN STD CHANNEL)                 |    | C                                                                                     | C9 x 13.4                                        |
| M                                                                                    | 8X8 M 34.3                                                                                              | M-SHAPE (MISC SHAPES OTHER THAN W, BP, S, & C) |    | M                                                                                     | M8 x 34.3                                        |
| M                                                                                    | 8 M 17                                                                                                  |                                                |                                                                                       |                                                                                       | M8 x 17                                          |
| Jr                                                                                   | 7 Jr. 5.5                                                                                               |                                                |                                                                                       |                                                                                       | M7 x 5.5                                         |
|     | 12 X 4  44.5           | MC-SHAPE (CHANNELS OTHER THAN AMERICAN STD)    |    | MC                                                                                    | MC 12 x 45                                       |
| Jr  | 10 Jr  8A              |                                                |                                                                                       |                                                                                       | MC 12 x 12.6                                     |
|                                                                                      |                                                                                                         | ANGLES:                                        |                                                                                       |                                                                                       |                                                  |
|     |  3 x 3 x $\frac{1}{4}$ | EQUAL LEG                                      |    | L                                                                                     | L 3 x 3 x $\frac{1}{4}$                          |
|     |  7 x 4 x $\frac{1}{2}$ | UN-EQUAL LEG                                   |    | L                                                                                     | L 7 x 4 x $\frac{1}{2}$                          |
|                                                                                      |                                                                                                         | TEES, STRUCTURAL:                              |    |                                                                                       |                                                  |
| ST                                                                                   | ST 5 WF 10.5                                                                                            | CUT FROM W-SHAPE                               |                                                                                       | WT                                                                                    | WT 12 x 38                                       |
|                                                                                      |                                                                                                         | CUT FROM S-SHAPE                               |                                                                                       | ST                                                                                    | ST 12 x 38                                       |
|                                                                                      |                                                                                                         | CUT FROM M-SHAPE                               |                                                                                       | MT                                                                                    | MT 12 x 38                                       |
| PL                                                                                   | PL 18 x $\frac{1}{2}$ x 2'-6"                                                                           | PLATE                                          |  | PL                                                                                    | PL $\frac{1}{2}$ x 18" x 30"                     |
| BAR                                                                                  | BAR 2 $\frac{1}{2}$ x $\frac{1}{4}$                                                                     | FLAT BAR                                       |  | BAR                                                                                   | BAR 2 $\frac{1}{2}$ x $\frac{1}{4}$              |
|   |  6 $\phi$            | PIPE, STRUCTURAL                               |  |  | PIPE 4 STD<br>PIPE 4X - STRG<br>PIPE 4 XX - STRG |

Figure 7-1 — Structural shapes and designations.

## W-Shape

The W shape is a structural member whose cross section forms the letter H and is the most widely used structural member. It is designed so that its flanges provide strength in a horizontal plane, while the web gives strength in a vertical plane. W-shapes are used as beams, columns, and truss members, and in other load-bearing applications.

## Bearing Pile

The bearing pile (HP-shape) is almost identical to the W-shape. The only difference is that the flange thickness and web thickness of the bearing pile are equal, whereas the W-shape has different web and flange thicknesses.

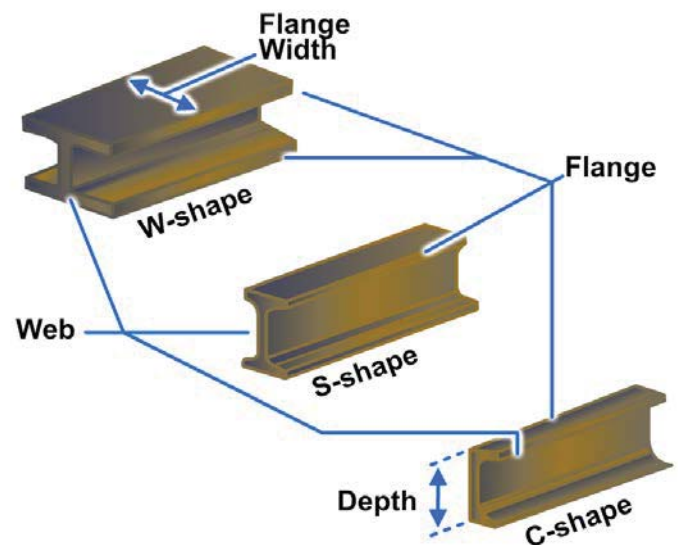


Figure 7-2 — Cross section view of the W-, S-, and C-shape structural members.

## S-Shape

The S-shape (American Standard I-beam) is distinguished by its cross section being shaped like the letter I. S-shapes are used less frequently than W-shapes since the S-shapes possess less strength and are less adaptable than W-shapes.

## C-Shape

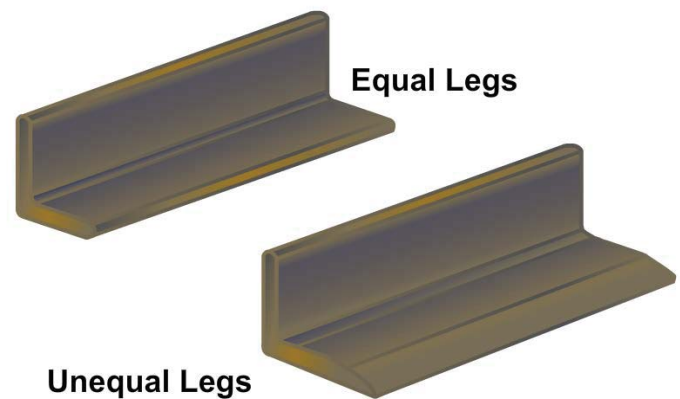
The C-shape (American Standard channel) has a cross section somewhat similar to the letter C. It is especially useful in locations where a single flat face without outstanding flanges on one side is required. The C-shape is not very efficient for a beam or column when used alone. However, efficient built-up members may be constructed of channels assembled together with other structural shapes and connected by rivets or welds.

## Channels

A cross section of a channel is similar to the squared letter C. Channels are identified by their nominal depth and weight per foot. For example, the American Standard channel notation C9 x 13.4 in *Figure 7-1* shows a nominal depth of 9 inches and a weight of 13.4 pounds per linear foot. Channels are principally used in locations where a single flat face without outstanding flanges on a side is required. However, the channel is not very efficient as a beam or column when used alone. But the channels may be assembled together with other structural shapes and connected by rivets or welds to form efficient built-up members.

## Angles

An angle (*Figure 7-3*) is a structural shape whose cross section resembles the letter L. Two types are commonly used: an equal-leg angle and an unequal-leg angle. The angle is identified by the dimension and thickness of its legs, for example, angle 6 inches by 4 inches by 1/2 inch. The dimension of the legs should be obtained by measuring along the outside of the backs of the legs. When an angle has unequal legs, the dimension of the wider leg is given first, as in the example just cited. The third dimension applies to the thickness of the legs, which always have equal thickness. Angles may be used in combinations of two or four to form main members. A single angle may also be used to connect main parts together.



**Figure 7-3 — Angles.**

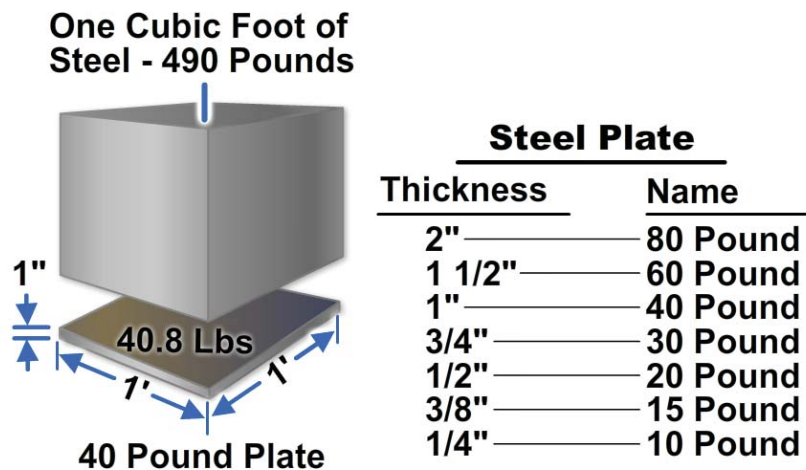
## Plates

Generally, a main point to remember about plate is that it has a width of greater than 8 inches and a thickness of 1/4 inch or greater. Plates are generally used as connections between other structural members or as component parts of built-up structural members. Plates cut to specific sizes may be obtained in widths ranging from 8 inches to 120 inches or more, and in various thicknesses. The edges of these plates may be cut by shears (sheared plates) or be rolled square (universal mill plates).

Frequently, plates are referred to by their thickness and width in inches, as plate 1/2 inch x 24 inches. The length in all cases is given in inches. Notice in *Figure 7-4* that 1 cubic foot of steel weighs 490 pounds. This weight divided by 12 equaling 40.8, which is the weight (in pounds) of a steel plate 1 foot square and 1-inch thick. The fractional portion is normally dropped and 1-inch plate is called a

40-pound plate. In practice, you may hear plate referred to by its approximate weight per square foot for a specified thickness. An example is 20-pound plate, which indicates a 1/2-inch plate.

The designations generally used for flat steel have been established by the American Iron and Steel Institute (AISI). Flat steel is designated as bar, strip, sheet, or plate, according to the thickness of the material, the width of the material, and (to some extent) the rolling process to which it was subjected.



**Figure 7-4 — Weight and thickness of a steel plate.**

## Tees

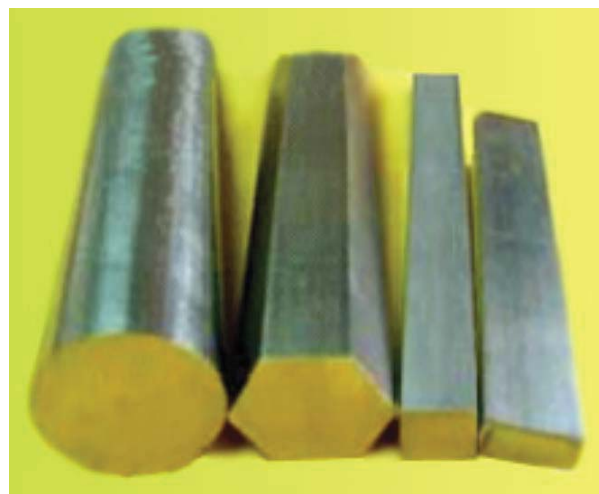
A structural tee is made by slitting a standard I- or H- beam through the center of its web, thus forming two T-shapes from each beam. In dimensioning, the structural tee symbol is preceded by the letters ST. For example, the symbol ST 5 WF 10.5 means the tee has a nominal depth of 5 inches, a wide flange, and weighs 10.5 pounds per linear foot. A rolled tee is a manufactured shape. In dimensioning, the rolled tee symbol is preceded by the letter T. The dimension T 4 x 3 x 9.2 means the rolled T has a 4-inch flange, a nominal depth of 3 inches, and a weight of 9.2 pounds per linear foot.

## Zee

These shapes are noted by depth, flange width, and weight per linear foot. Therefore, Z 6 x 3 1/2 x 15.7 means the zee is 6 inches in depth, has a 3 1/2-inch flange, and weighs 15.7 pounds per linear foot.

## Flat Bar

The structural shape referred to as bar has a width of 8 inches or less and a thickness greater than 3/16 of an inch. The edges of bars usually are rolled square, like universal mill plates. The dimensions are expressed in a similar manner as that for plates, for instance, bar 6 inches by 1/2 inch. Bars are available in a variety of cross-sectional shapes—round, hexagonal, octagonal, square, and flat. Four different shapes are illustrated in *Figure 7-5*. Both squares and rounds are commonly used as bracing members of light structures. Their dimensions, in inches, apply to the side of the square or the diameter of the round.

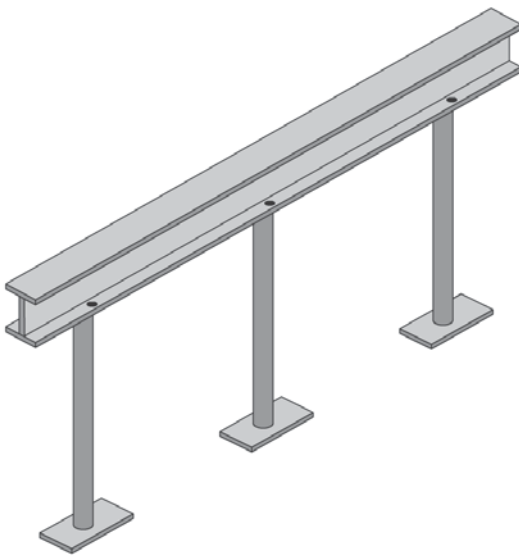


**Figure 7-5 — Bars.**

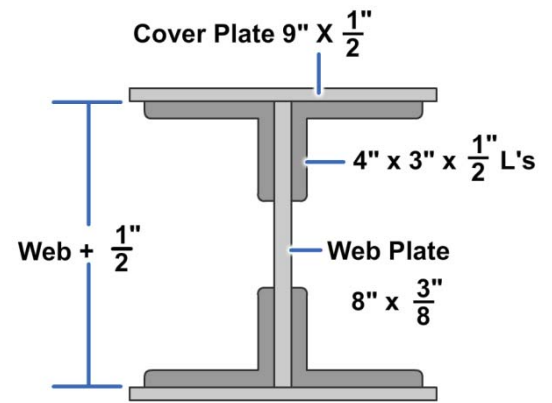
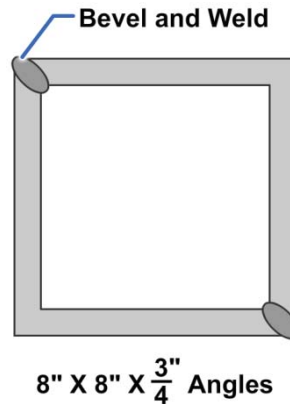
## Columns

Typically, wide flange members, as nearly square in cross section as possible, are used for columns, but sometimes large diameter pipe is used, even though pipe columns can present connecting difficulties when you are attaching other members (*Figure 7-6*). Columns may also be fabricated by welding or bolting together a number of other rolled shapes, usually angles and plates (*Figure 7-7*).





**Figure 7-6 — Girder span on pipe columns.**



**Figure 7-7 — Built-up column section.**

## Girders

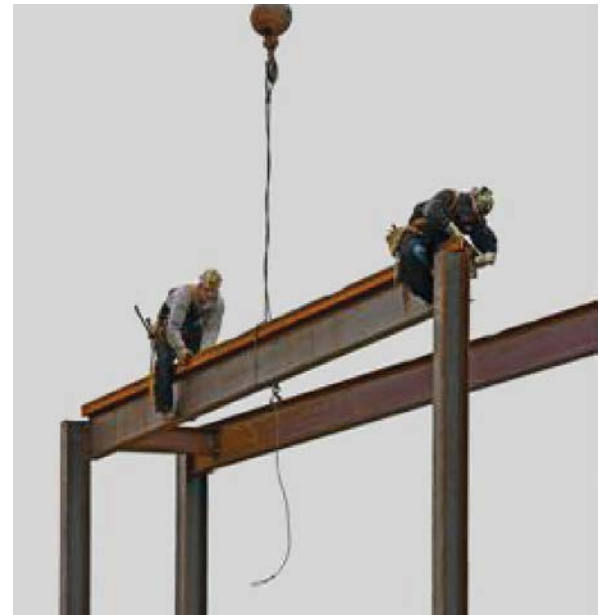
Girders are the primary horizontal members of a steel frame structure. They span from column to column and are usually connected on top of the columns with cap plates (bearing connections) (*Figure 7-8*). An alternate method is the seated connection (*Figure 7-9*). The girder is attached to the flange of the column using angles, with one leg extended along the girder flange and the other against the column. The function of the girders is to support the intermediate floor beams.

## Members

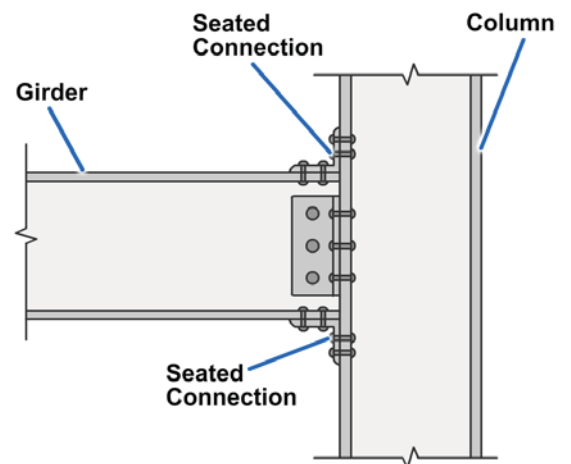
The main parts of a structure are the load-bearing members. These support and transfer the loads on the structure while remaining equal to each other. The places where members are connected to other members are

called joints. The total sum of the load supported by the structural members at a particular instant is equal to the total dead load plus the total live load.

The total dead load is the total weight of the structure, which gradually increases as the structure rises and remains constant once it is complete. The total live load is the total weight of movable objects, such as people, furniture, and bridge traffic, the structure happens to be supporting at a particular instant.

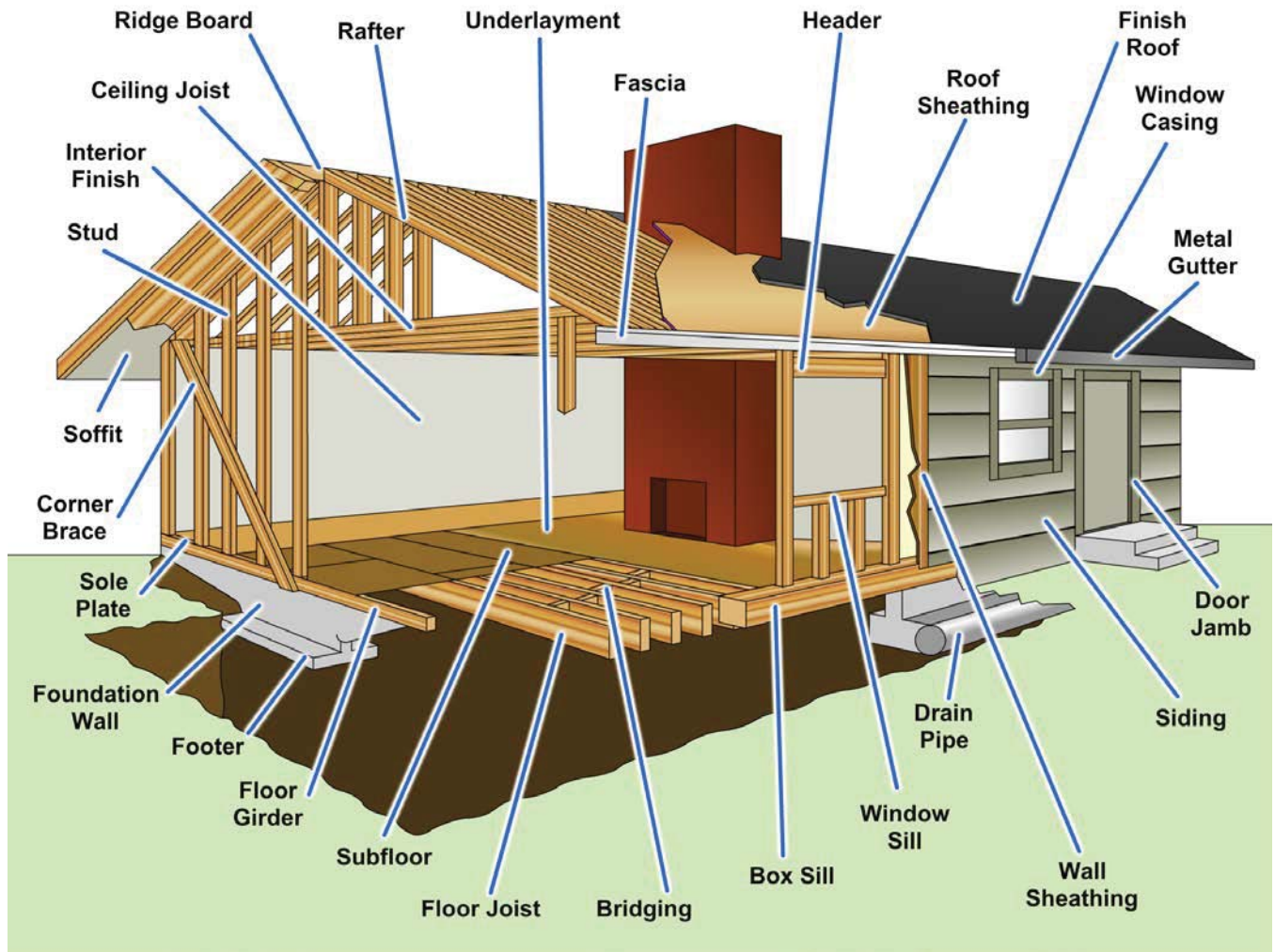


**Figure 7-8 — Girder span on a wide flange column.**



**Figure 7-9 — Seated connections.**

A structure transmits live loads through the various load-bearing structural members to the ultimate support of the earth. Look at *Figure 7-10*, which illustrates both horizontal and vertical members of a typical light frame structure.



**Figure 7-10 — Typical light frame construction.**

First, horizontal members provide immediate or direct support for the live loads. Vertical members, in turn, support the horizontal members. Finally, the vertical members are supported by foundations or footings, which are supported by the earth. The weight of the roof material is distributed over the top supporting members and transferred through all joining members to the soil.

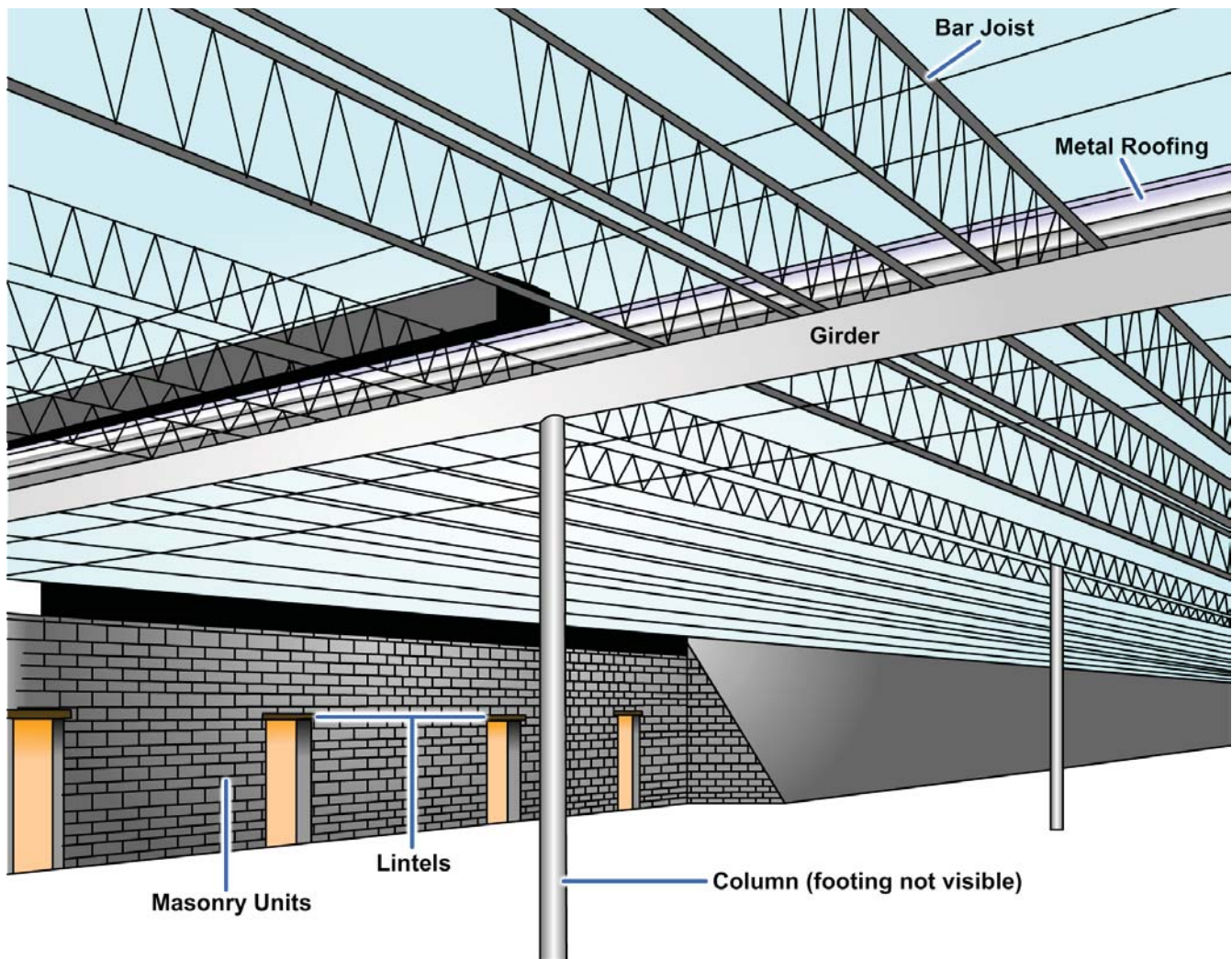
The ability of the earth to support a load is called its soil-bearing capacity. This varies considerably with different types of soil. A soil of a given bearing capacity bears a heavier load on a wide foundation or footing than on a narrow one. Loads are covered in much greater detail in the Builder Advanced rate training manual. This section is meant to be a brief introduction to the concept of load.

### **Vertical Members**

In heavy construction, vertical structural members are high-strength columns. In large buildings, these are called pillars. Outside wall columns and inside bottom floor columns usually rest directly on footings. Outside wall columns usually extend from the footing or foundation to the roof line. Inside bottom floor columns extend upward from footings or foundations to the horizontal members, which,

in turn, support the first floor or roof, as shown in *Figure 7-11*. Upper floor columns are usually located directly over lower floor columns.

In building construction, a pier, sometimes called a short column, rests either directly on a footing, as shown in the lower center of *Figure 7-12*, or is simply set or driven into the ground. Building piers usually support the lowermost horizontal structural members.



**Figure 7-11 — Typical concrete masonry and steel structure.**

The chief vertical structural members in light frame construction are called studs, shown in *Figures 7-10 and 7-12*. They are supported by horizontal members called sills or soleplates, shown in *Figure 7-12*. Corner posts are enlarged studs located at the building corners. At one time, in full frame construction, a corner post was usually a solid piece of larger timber. Most modern construction uses built-up corner posts. These consist of various members of ordinary studs nailed together in various ways.

In bridge construction, a pier is a vertical member that provides intermediate support for the bridge superstructure, as shown in *Figure 7-13*.



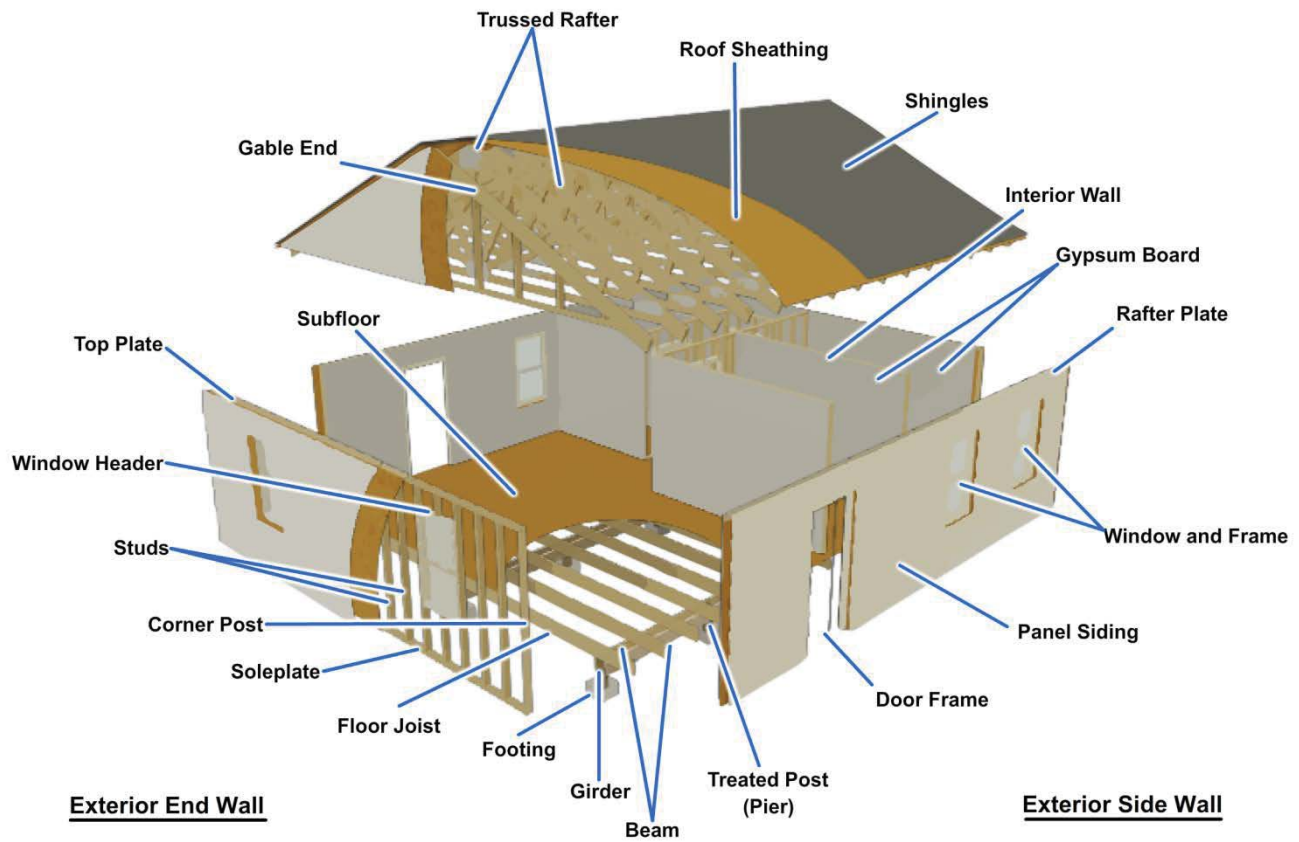


Figure 7-12 — Exploded view of a typical light frame house.

## Horizontal Members

Any horizontal load-bearing structural member that spans a space and is supported at both ends is considered a beam. A member fixed at only one end is called a cantilever beam. A joist is a horizontal supporting member generally smaller than a beam. Steel members that consist of solid pieces of regular structural steel are referred to as structural shapes. The girder, shown in *Figure 7-11*, is a structural shape. Other prefabricated, open-web, structural-steel shapes are called bar joists, also shown in *Figure 7-11*.

Horizontal structural members that support the ends of floor beams or joists in wood frame construction are called sills or girders, shown in *Figures 7-10* and *7-12*, depending on the type of framing and the location of the member in the structure. Horizontal members that support studs are called soleplates. They may also have other names, depending on the type of framing. Horizontal members that support the wall ends of rafters are called rafter plates. Horizontal members that support the weight of concrete or masonry walls above door and window openings are called lintels (*Figure 7-11*).

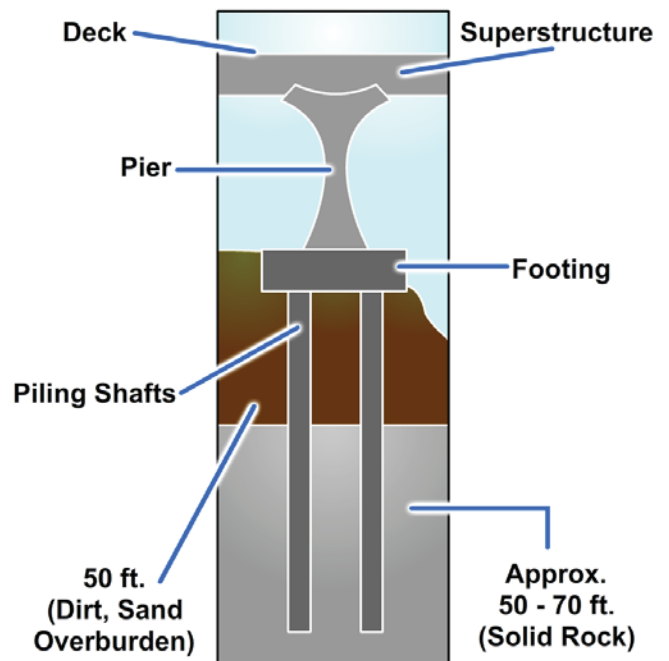


Figure 7-13 — Pier supporting bridge superstructure.



The horizontal or inclined members that provide support to a roof are called rafters (*Figure 7-14*). The lengthwise member at a right angle to the rafters, which supports the peak ends of the rafters in a roof, is called the ridge. The ridge may be called a ridgeboard, the ridge piece, or the ridgepole. Lengthwise members other than ridges are called purlins. In wood frame construction, the wall ends of rafters are supported on horizontal members called rafter plates, which are in turn supported by the outside wall studs. In concrete or masonry construction, the wall ends of rafters may be anchored directly on the walls or on plates bolted to the walls.

## Trusses

A beam of given strength, without intermediate supports below; can support a given load over only a specific maximum span. When the span is wider than this maximum space, the beam requires intermediate supports such as columns. Sometimes it is either not feasible or impossible to increase the beam size or to install intermediate supports. In such cases, a truss provides the required support. A truss is a combination of members, such as beams, bars, and ties, usually arranged in triangular units, that forms a rigid framework for supporting loads over a span.

The basic components of a roof truss are the top and bottom chords and the web members. The top chords serve as roof rafters. The bottom chords act as ceiling joists. The web members run between the top and bottom chords. The truss parts are usually made of 2 by 4 inch or 2 by 6 inch material and tied together with metal or plywood gusset plates, shown in *Figure 7-14*.

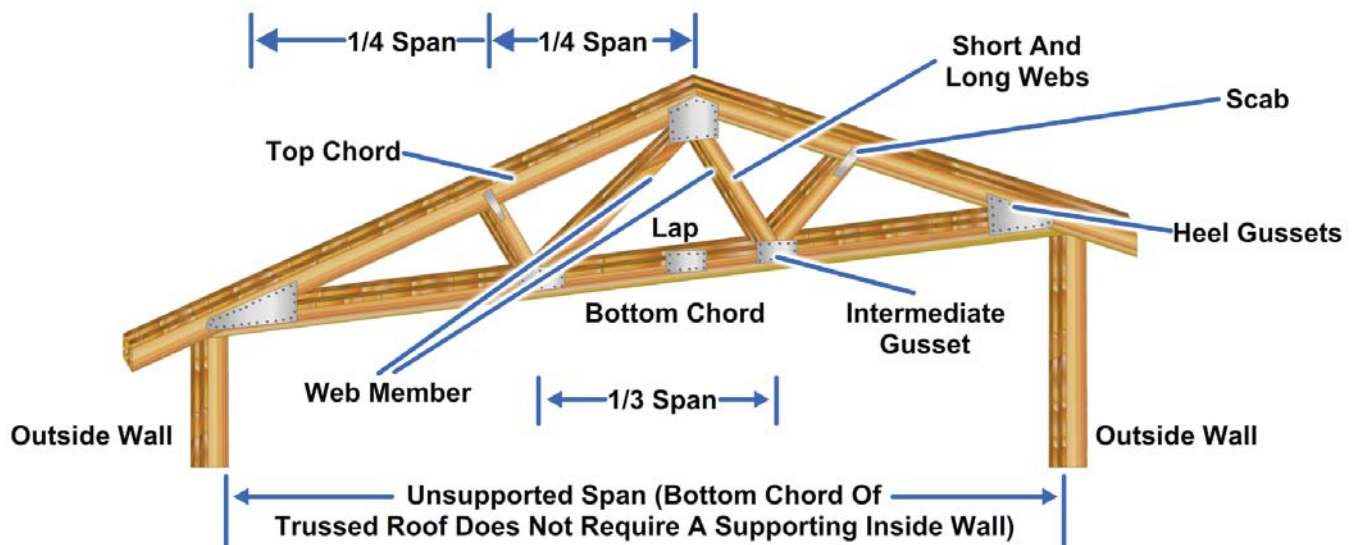


Figure 7-14 — A truss rafter.

## WELDED AND RIVETED STEEL STRUCTURES

The following paragraphs will discuss welded and riveted steel structures and will give examples of both methods used to make trusses.

### Welded Steel Structures

Generally, welded connections are framed or seated just as they are in riveted connections, which we will discuss later. However, welded connections are more flexible. The holes used to bolt or pin pieces together during welding are usually drilled in the fabrication shop. Beams are not usually welded directly to columns. The procedure produces a rigid connection and results in severe bending that stresses the beam, which must be resisted by both the beam and the weld.

## Welding Symbol

Drawings contain special symbols to specify the weld location, type of joint, and size and amount of weld metal to be deposited in the joint. The American Welding Society (AWS) has standardized them. A welder will see them whenever he or she performs a welding job from a set of prints, so you need to be familiar with all the elements of a standard welding symbol, and the location and meaning of the basic weld symbols.

A standard welding symbol (*Figure 7-15*) is:  
reference line + arrow + tail.

The reference line is the foundation. Weld symbols, dimensions, and other data are applied to it. The arrow connects the reference line to the joint or area to be welded. The direction of the arrow has no bearing on the significance of the reference line. The tail of the welding symbol is used only when necessary to include a process, specification, or other reference information.

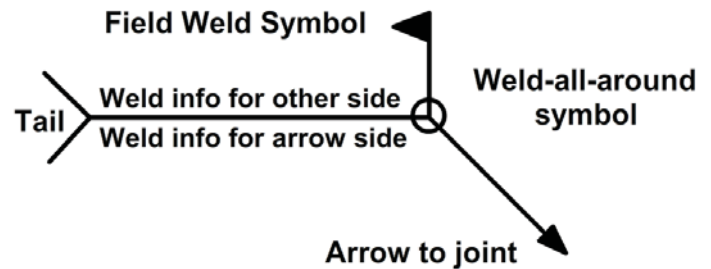


Figure 7-15 — Standard welding symbol.

| Fillet | Plug or Slot | Spot or Projection | Seam | Back or Backing | Melt Thru | Surfacing | Flange |
|--------|--------------|--------------------|------|-----------------|-----------|-----------|--------|
|        |              |                    |      |                 |           |           |        |

### Groove

| Square | V | Bevel | U | J | Flare - V | Flare - Bevel |
|--------|---|-------|---|---|-----------|---------------|
|        |   |       |   |   |           |               |

### Basic Arc and Gas Weld Symbols

| Weld all around | Flag toward tail field weld | Contour |        |         |
|-----------------|-----------------------------|---------|--------|---------|
|                 |                             | Flush   | Convex | Concave |
|                 |                             |         |        |         |

### Supplementary Symbols

Figure 7-16 — Standard weld symbols.

How the weld symbol is applied to the reference line is shown in *Figure 7-17*. Notice that the vertical leg of the weld symbol is shown drawn to the left of the slanted or curved leg of the symbol. Regardless of whether the symbol is for a fillet, bevel, J-groove, or flare-bevel weld, the vertical leg is always drawn to the left. The significance of the weld symbol's position on the reference line is depicted in *Figure 7-18*.

### Type of Weld Symbols

Weld symbols refer to the symbols for a specific type of weld, such as fillet, groove, butt, surfacing, plug, or slot.

The weld symbol (*Figure 7-16*) is only part of the information required in the welding symbol. When used to disseminate information, the term welding symbol refers to the total symbol, which includes all the weld symbols needed to specify the weld(s) required.

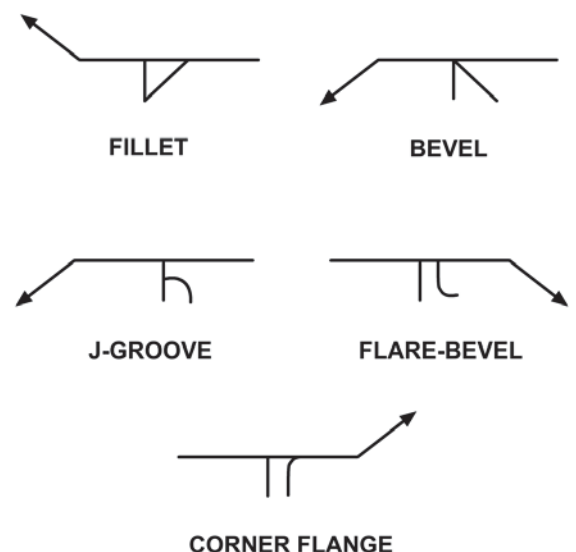
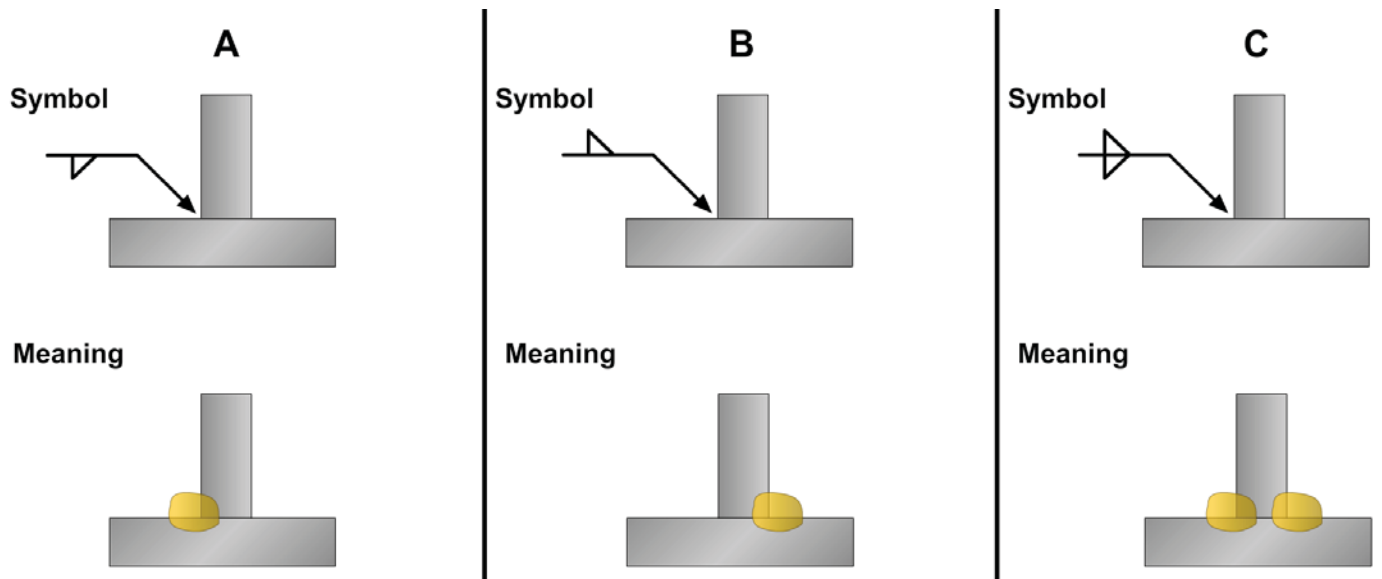


Figure 7-17 — Example of weld symbols applied to a reference line.



**Figure 7-18 — Example of specifying weld location.**

When only one edge of a joint is to be beveled, it is necessary to show which member is to be beveled (*Figure 7-19*). When such a joint is specified, the arrow of the welding symbol points with a definite break toward the member to be beveled. Other weld symbols may be added to a welding symbol as necessary to communicate all the information needed for the weld.

However, regardless of the direction of the arrow, all information applied to the reference line on a welding symbol is read from left to right. A listing of welding symbols is shown in *Figure 7-20*.



**Figure 7-19— Example of arrowhead indicating bevel plate.**

| Location Significance                             | Fillet     | Plug or Slot | Spot or Projection | Stud           | Seam                                                                                                                                                                                           | Back or Backing | Surfacing     | Flange Corner          | Flange Edge |
|---------------------------------------------------|------------|--------------|--------------------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|---------------|------------------------|-------------|
| Arrow Side                                        |            |              |                    |                |                                                                                                                                                                                                |                 |               |                        |             |
| Other Side                                        |            |              |                    | Not Used       |                                                                                                                                                                                                |                 | Not Used      |                        |             |
| Both Sides                                        |            | Not Used     | Not Used           | Not Used       | Not Used                                                                                                                                                                                       | Not Used        | Not Used      | Not Used               | Not Used    |
| No arrow side or other side significance          | Not Used   | Not Used     |                    | Not Used       |                                                                                                                                                                                                | Not Used        | Not Used      | Not Used               | Not Used    |
| Location Significance                             | Groove     |              |                    |                |                                                                                                                                                                                                |                 |               | Scarf for Brazed Joint |             |
|                                                   | Square     | V            | Bevel              | U              | J                                                                                                                                                                                              | Flare - V       | Flare - Bevel |                        |             |
| Arrow Side                                        |            |              |                    |                |                                                                                                                                                                                                |                 |               |                        |             |
| Other Side                                        |            |              |                    |                |                                                                                                                                                                                                |                 |               |                        |             |
| Both Sides                                        |            |              |                    |                |                                                                                                                                                                                                |                 |               |                        |             |
| No arrow side or other side significance          |            | Not Used     | Not Used           | Not Used       | Not Used                                                                                                                                                                                       | Not Used        | Not Used      | Not Used               |             |
| Supplementary Symbols                             |            |              |                    |                |                                                                                                                                                                                                |                 |               |                        |             |
| Weld all around                                   | Field Weld | Melt Thru    | Consumable Insert  | Backing Spacer | Contour                                                                                                                                                                                        |                 |               |                        |             |
|                                                   |            |              |                    |                | Flush                                                                                                                                                                                          | Convex          | Concave       |                        |             |
|                                                   |            |              |                    |                |                                                                                                                                                                                                |                 |               |                        |             |
| Basic Joints                                      |            |              |                    |                |                                                                                                                                                                                                |                 |               |                        |             |
| Identification of Arrow Side and Other Side Joint |            |              |                    |                |                                                                                                                                                                                                |                 |               |                        |             |
| Butt Joint                                        |            |              |                    |                | Corner Joint                                                                                                                                                                                   |                 |               |                        |             |
|                                                   |            |              |                    |                |                                                                                                                                                                                                |                 |               |                        |             |
| T - Joint                                         |            |              |                    |                | Lap Joint                                                                                                                                                                                      |                 |               |                        |             |
|                                                   |            |              |                    |                |                                                                                                                                                                                                |                 |               |                        |             |
| Edge Joint                                        |            |              |                    |                | Process Abbreviations                                                                                                                                                                          |                 |               |                        |             |
|                                                   |            |              |                    |                | <p>Where process abbreviations are to be included in the tail of the welding symbol, reference is made to Table 1. Designation of Welding and Allied Processes by Letters, of AWS A2.4-86.</p> |                 |               |                        |             |

### Location of Elements of a Welding Symbol

Finish symbol

Contour symbol

Root opening: depth of filling for plug and slot welds

Groove weld size

Depth of preparation; size and strength for certain welds

Specification, process, or other reference

Tail (Tail omitted when reference is not used)

Basic weld symbol or detail reference

Groove angle, included angle of countersink for plug welds

Length of weld

Pitch (center-to-center spacing) of welds

Field weld symbols

Arrow connecting reference line to arrow side member of joint or arrow side of joint

Weld-all-around symbol

Reference line

Number of spot, stud, or projection welds

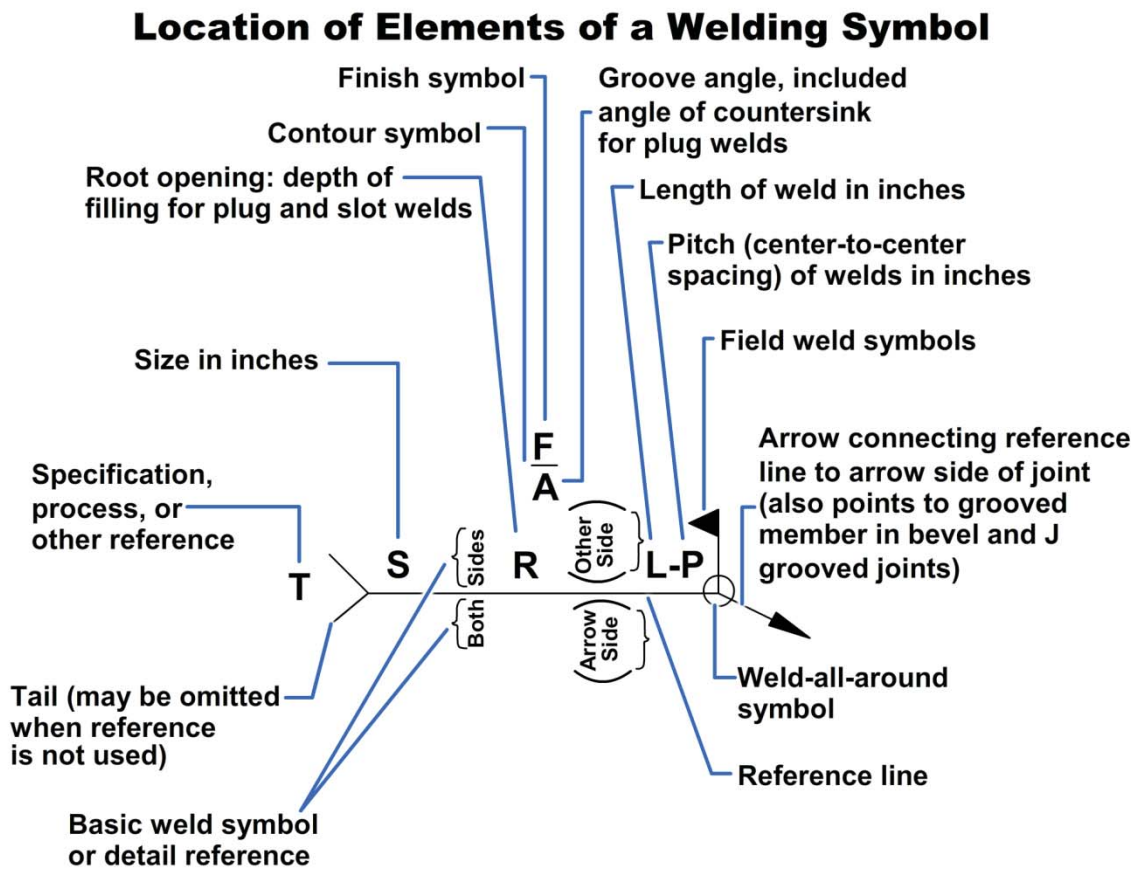
Elements in this area remain as shown when tail and arrow are reversed

(N)

Figure 7-20 — Typical welding symbols.

Dimensioning

Notice in *Figure 7-21* that some specified information has designated locations.



**Figure 7-21 — Standard location for specific elements of a welding symbol.**

The size, length, pitch (center-to-center spacing), groove angle, and root opening of a weld all have designated locations. These locations are determined by the side of the reference line on which the weld symbol is placed.

**Supplementary**

Besides the basic weld symbols, the welding symbol may include supplementary symbols (*Figure 7-22*). Contour symbols show how the face is to be formed; finish symbols indicate the method to use to form the contour.

A finish symbol (when used) shows the method of finish, C represents chipping, M means machining, and G indicates grinding, not the degree of finish. How contour and finish symbols are applied to a welding symbol is illustrated in *Figure 7-23*. This symbol indicates the weld is to be ground flush. Also, notice that the symbols are placed on the same side of the reference line as the weld symbol.

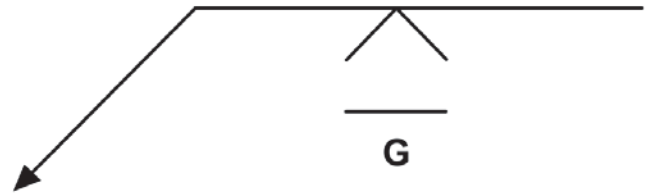
| CONTOUR         |        |            |
|-----------------|--------|------------|
| FLUSH           | CONVEX | CONCAVE    |
|                 |        |            |
| WELD ALL AROUND |        | FIELD WELD |
|                 |        |            |

**Figure 7-22 — Supplementary symbols.**



Another supplementary symbol is the weld-all-around symbol. When this symbol is placed on a welding symbol, welds are to continue all around the joint.

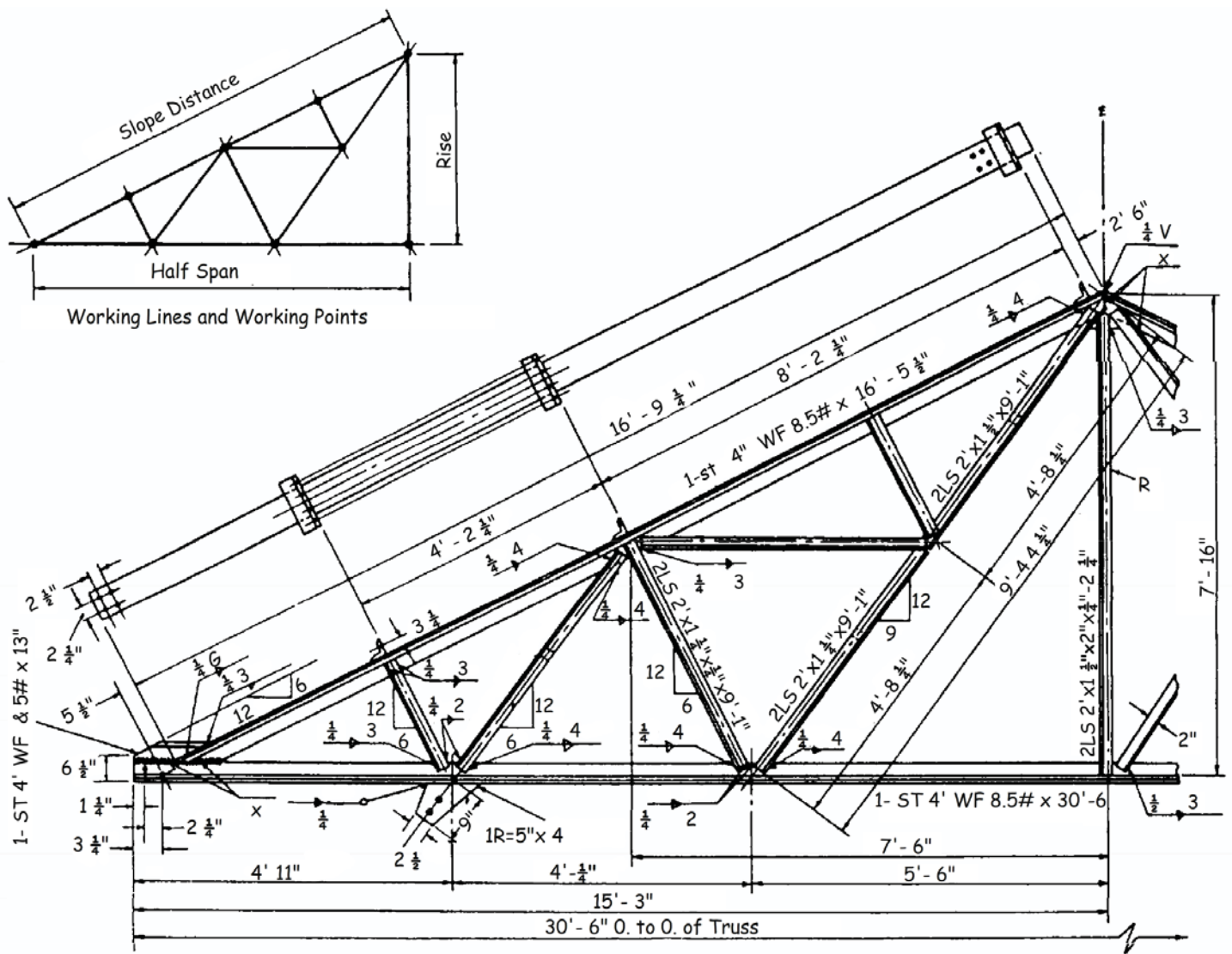
Yet another symbol on *Figure 7-22* is the field weld symbol, a black flag that points toward the tail of the welding symbol. For welds that cannot be made in the shop, for size, transportation, constructability, or other reasons, this symbol directs the welder to make the weld in the field, which could be "in situ" or on site.



**Figure 7-23 — Welding finish symbol.**

## Welded Steel Trusses

A drawing of a typical welded steel truss is illustrated in *Figure 7-24*. When you interpret the welding symbols, you will see that most of them show that the structural angles will be fillet welded. The fillet will have a  $\frac{1}{4}$  inch radius (thickness) on both sides and will run along the angle for 4 inches.

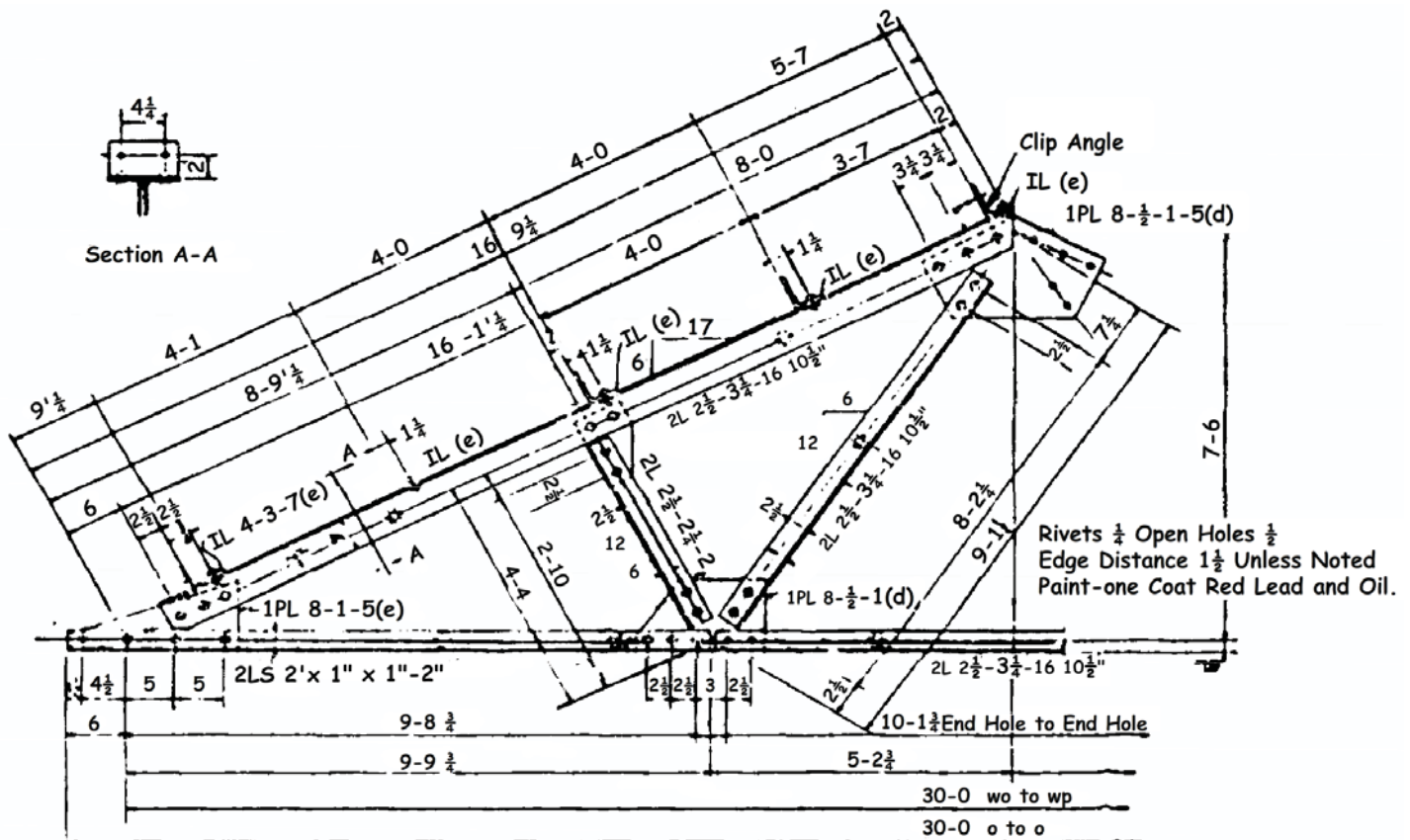


**Figure 7-24 — Welded steel truss.**

## Riveted Steel Structures

Steel structural members are riveted in the shop where they are fabricated to the extent allowed by shipping conditions. During fabrication, all rivet holes are punched or drilled whether the rivets are to be driven in the field or in the shop.

Look at the shop fabrication drawing of a riveted steel roof truss in *Figure 7-25*. At first look, it appears cluttered and hard to read. This is caused by the many dimensions and other pertinent facts required on the drawing, but you can read it once you understand what you are looking for, as we will explain in the next paragraphs.



**Figure 7-25 — Riveted steel truss shop drawing.**

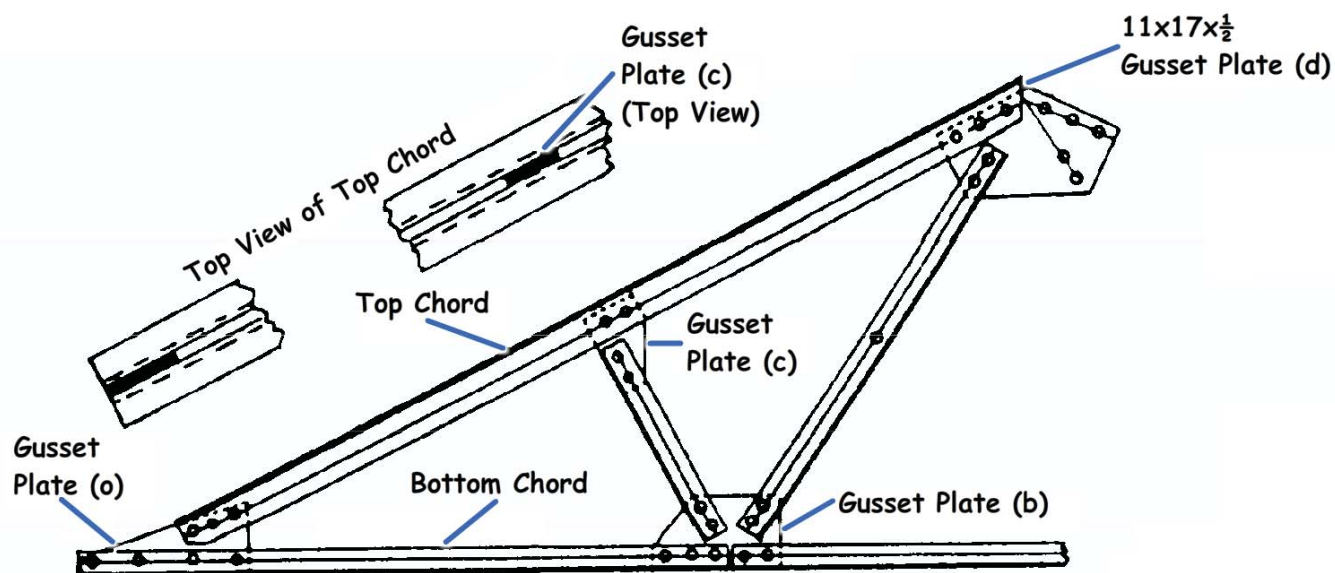
The top chord is made up of two angles labeled with specification  $2L\ 4 \times 3\ \frac{1}{2} \times \frac{5}{16} \times 16'-5\ \frac{1}{2}''$ . This means the chord is 4 inches by 3  $\frac{1}{2}$  inches by  $\frac{5}{16}$  inch thick and 16 feet 5  $\frac{1}{2}$  inches long.

The top chord also has specification  $IL\ 4 \times 3 \times \frac{3}{8} \times 7'(e)$ . This means it has five clip angles attached, and each of them is an angle 4 inches by 3 inches by  $\frac{3}{8}$  inch thick and 7 inches in length.

The gusset plate (a) on the lower left of the view is labeled  $PL\ 8 \times \frac{3}{8} \times 1'-5'(a)$ . That means it is 8 inches at its widest point,  $\frac{3}{8}$  inch thick, 1 foot 5 inches long at its longest point.

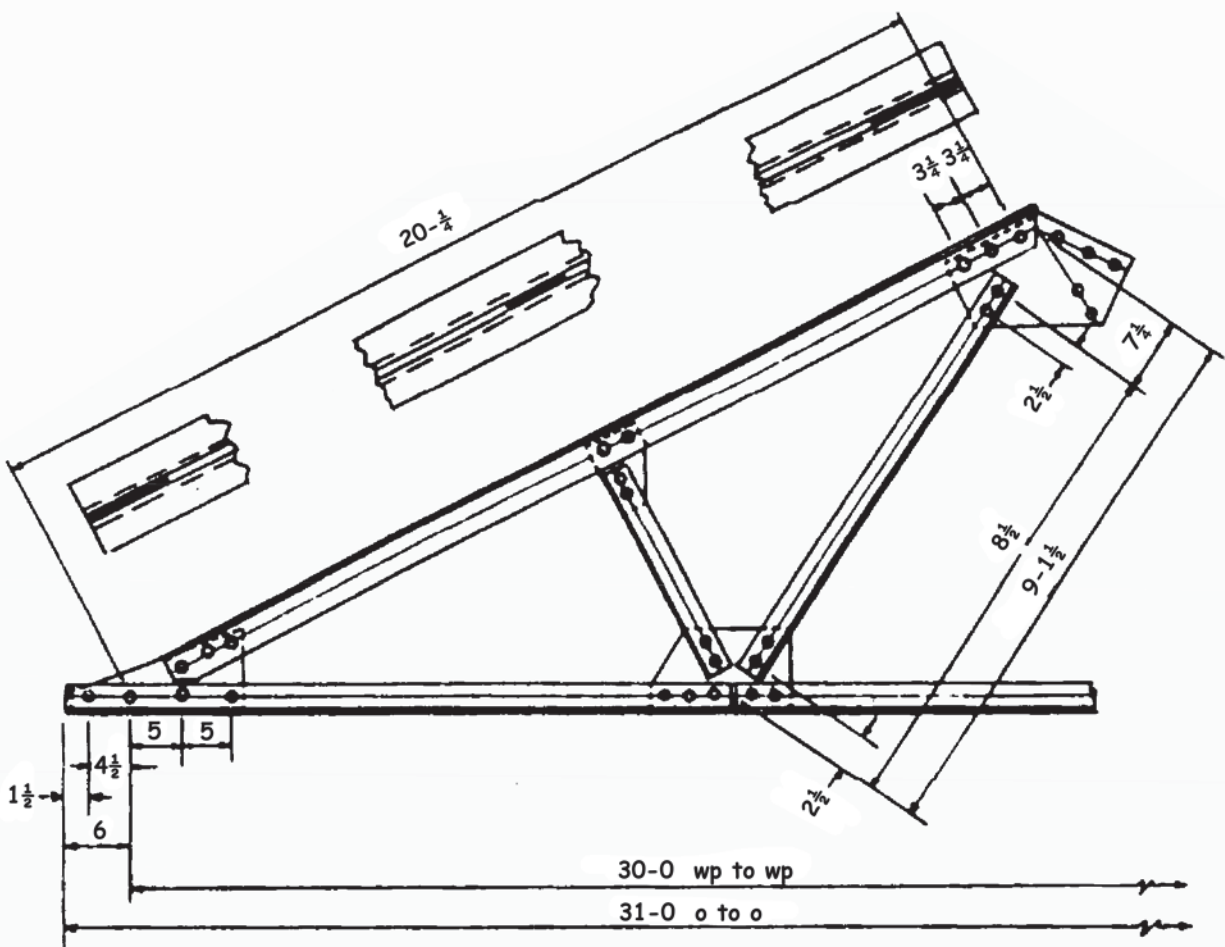
The bottom chord is made up of two angles  $2\ \frac{1}{2}$  inches by 2 inches by  $\frac{5}{16}$  inches by 10 feet  $3\ \frac{7}{16}$  inches which are connected to gusset plates A and B, and two more angles  $2\ \frac{1}{2}$  inches by 2 inches by  $\frac{1}{4}$  inches by 10 feet  $4\ \frac{1}{8}$  inches which are connected to gusset plate B and continue to the other half of the truss. Two more angles are connected to gusset plates C and B on the top and bottom chords; they are  $2\ \frac{1}{2}$  inches by 2 inches by  $\frac{1}{4}$  inches by 2 feet  $10\ \frac{1}{2}$  inches. The other member between the top and bottom chords, connected to gusset plate B and the purlin gusset D, is made up of two angles  $2\ \frac{1}{2}$  inches by 2 inches by  $\frac{1}{4}$  inches by 8 feet 5 inches.

In *Figure 7-26*, the same truss is shown with only the names of some members and the sizes of the gusset plates (A, C, and D) between the angles.



**Figure 7-26 — Nomenclature, member sizes and top view of the riveted steel truss.**

In *Figure 7-27*, the same truss is shown with only a few of the required dimensions to make it easier to read the complete structural shop drawing.



**Figure 7-27 — Dimensions of the riveted steel truss.**

Most of the rivets will be driven in the shop with the exception of five rivets in the purlin gusset plate d and the two rivets shown connecting the center portion of the bottom chord, which is connected to gusset plate b. These seven rivets will be driven at the jobsite. Conventional symbols for rivets driven in the shop and in the field are shown in Figure 7-28.

## DRAWINGS OF STEEL STRUCTURES

Blueprints used for the fabrication and erection of steel structures usually consist of a group of different types of drawings such as layout, general, fabrication, erection, and falsework. These drawings are described in the following paragraphs.

### Layout Drawings

Layout drawings are also called general plans and profile drawings. They provide the necessary information on the location, alignment, and elevation of the structure and its principal parts in relation to the ground at the site. They also provide other important details, such as the nature of the underlying soil or the location of adjacent structures and roads. These drawings are supplemented by instructions and information known as written specifications.

### General Plans

General plans contain information on the size, material, and makeup of all main members of the structure, their relative position and method of connection, as well as the attachment of other parts of the structure. The number of general plan drawings supplied is determined by such factors as the size and nature of the structure, and the complexity of operations. General plans consist of plan views, elevations, and sections of the structure and its various parts. The amount of information required determines the number and location of sections and elevations.

| Description                                      | Symbol                                                                                |                                                                                       |
|--------------------------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
|                                                  | Plan                                                                                  | Section                                                                               |
| <b>Shop Rivets</b>                               |                                                                                       |                                                                                       |
| Two Full Heads                                   |    |    |
| Countersunk & Chipped NS                         |    |    |
| Countersunk & Chipped FS                         |    |    |
| Countersunk & Chipped BS                         |    |    |
| Countersunk, not over 1/8 inch high NS           |    |    |
| Countersunk, not over 1/8 inch high FS           |    |    |
| Countersunk, not over 1/8 inch high BS           |    |    |
| Flattened to 1/4 inch for 1/2 and 3/8 rivets NS  |    |    |
| Flattened to 1/4 inch for 1/2 and 3/8 rivets FS  |    |    |
| Flattened to 1/4 inch for 1/2 and 3/8 rivets BS  |    |    |
| Flattened to 3/8 inch for 3/4 and over rivets BS |   |   |
| Flattened to 3/8 inch for 3/4 and over rivets FS |  |  |
| Flattened to 3/8 inch for 3/4 and over rivets BS |  |  |
| <b>Field rivets BS</b>                           |                                                                                       |                                                                                       |
| Two Full Heads                                   |  |  |
| Countersunk NS                                   |  |  |
| Countersunk FS                                   |  |  |
| Countersunk BS                                   |  |  |
| Notes:                                           | NS-near side<br>FS-far side<br>BS-both sides                                          |                                                                                       |

Figure 7-28 — Riveting symbols.



## **Fabrication Drawings**

Fabrication drawings, or shop drawings, contain necessary information on the size, shape, material, and provisions for connections and attachments for each member. This information is in enough detail to permit ordering the material for the member concerned and its fabrication in the shop or yard. Component parts of the members are shown in the fabrication drawing, as well as dimensions and assembly marks.

## **Erection Drawings**

Erection drawings, or erection diagrams, show the location and position of the various members in the finished structure. They are especially useful to personnel performing the erection in the field. For instance, the erection drawings supply the approximate weight of heavy pieces, the number of pieces, and other helpful data.

## **Falsework Drawings**

The term falsework refers to temporary supports of timber or steel required in the erection of difficult or important structures. When falsework is required on an elaborate scale, drawings similar to the general and detail drawings already described may be provided to guide construction. For simple falsework, field sketches may be all that is needed.

## **CONSTRUCTION PLANS**

Construction drawings are those in which as much construction information as possible is presented graphically, or by means of pictures (*Figure 7-29*). Most construction drawings consist of orthographic views. General drawings consist of plans and elevations drawn on relatively small scale. Detail drawings consist of sections and details drawn on a relatively large scale; we will discuss detail drawing in greater depth later in this chapter.



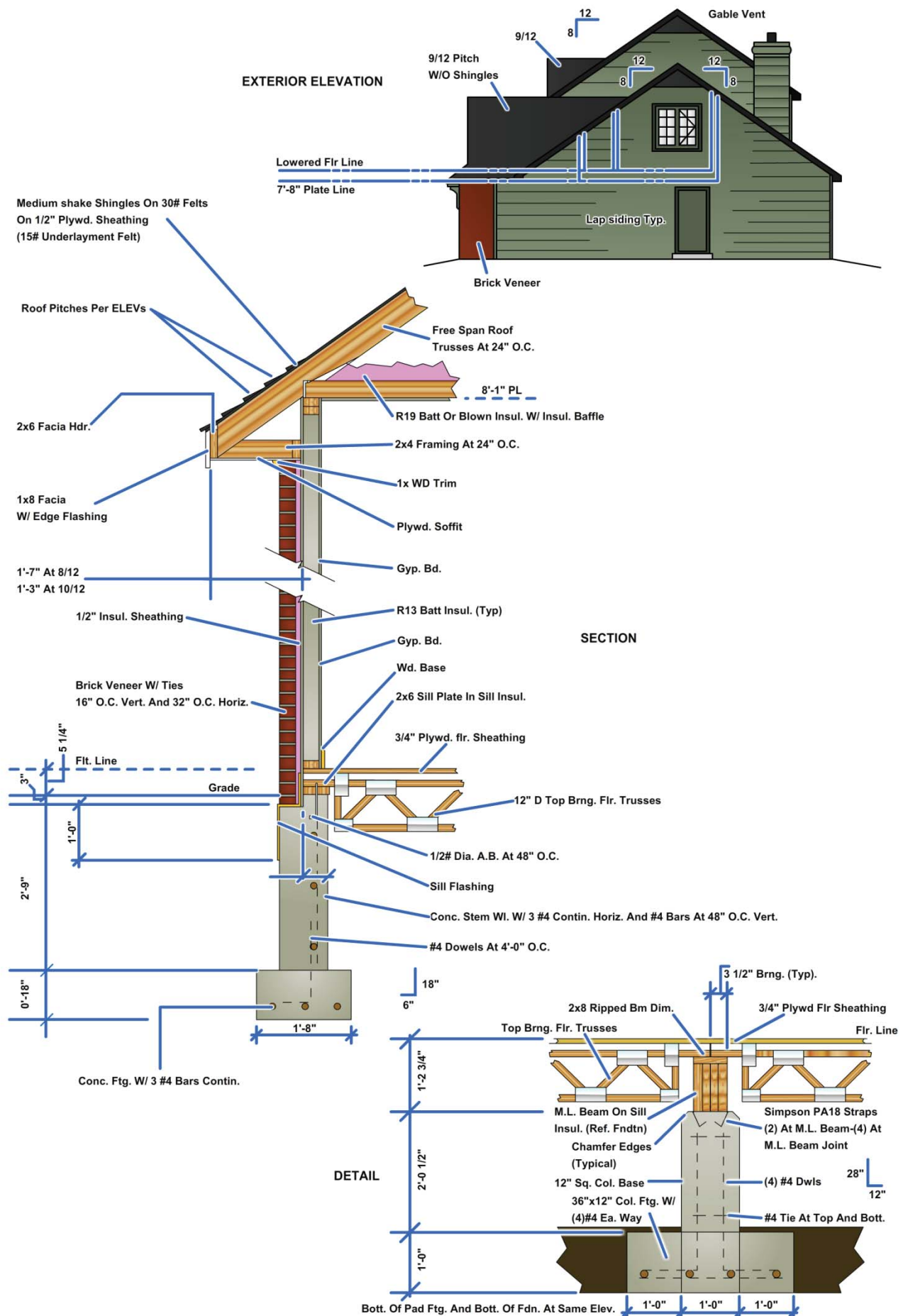


Figure 7-29 — Construction drawings.

## General Drawings

General drawings consist of plans (views from above) and elevations (side or front views) drawn on a relatively small scale. Both types of drawings use a standard set of architectural symbols. The most common construction plans are site plans, plot plans, foundation plans, floor plans, and framing plans. We will discuss each of them in the following paragraphs.

### Site Plan

The site plan shown in *Figure 7-30* shows the contours, boundaries, roads, utilities, trees, structures, and any other significant physical features on or near the construction site. It shows the locations of proposed structures in outline. This plan also shows corner locations relative to reference lines, shown on the plot, which can be located at the site. By showing both existing and finished contours, the site plan furnishes essential data for the graders and excavators.

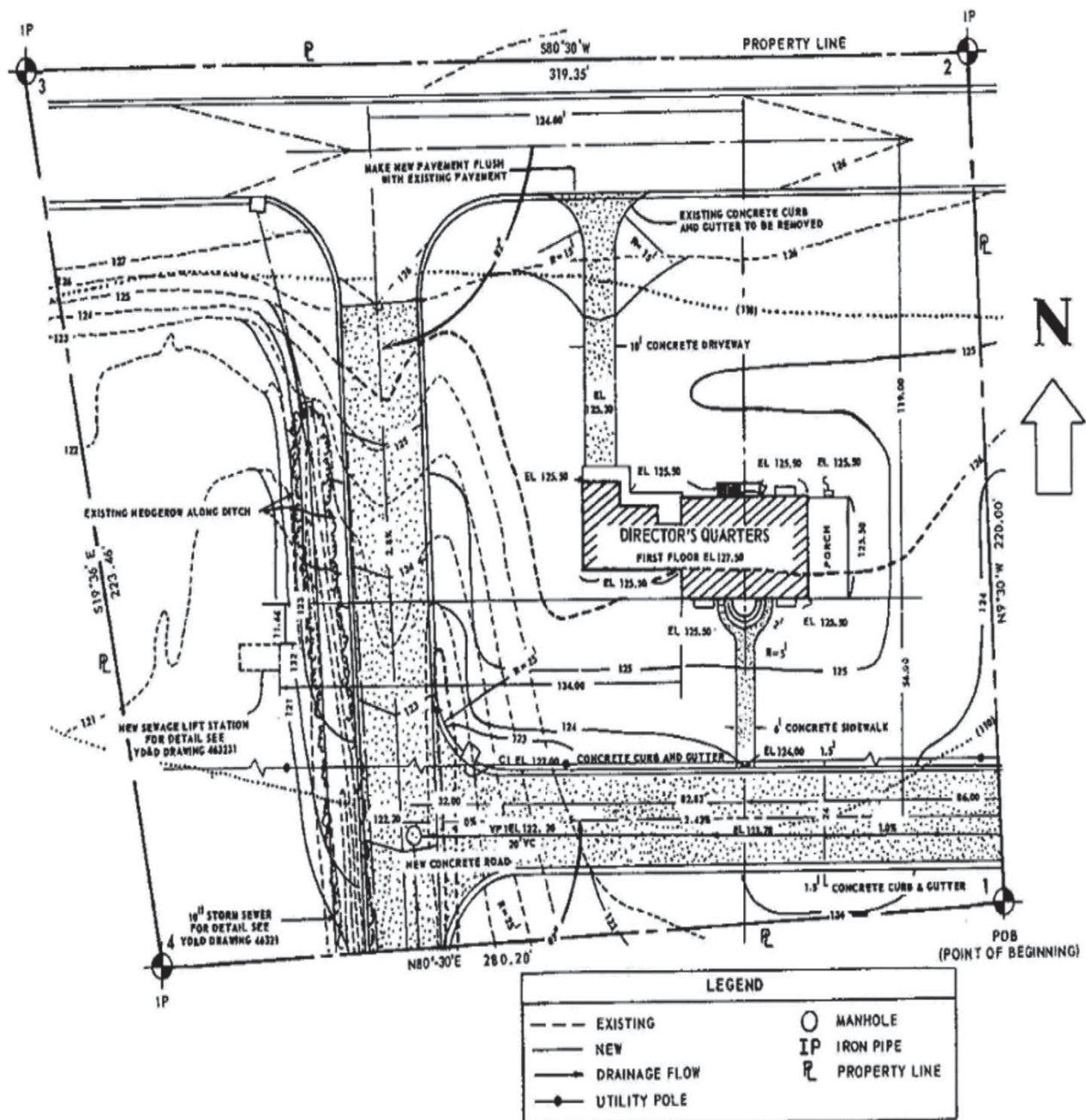


Figure 7-30 — Site plan.

## Plot Plans

The plot plan shows the survey marks, including the bench mark (BM), with the elevations and the grading requirements. Surveyors use the plot plan shown in *Figure 7-31* to set up the corners and perimeter of the building using batter boards and line stakes. The plot plan furnishes the essential data for laying out the building.

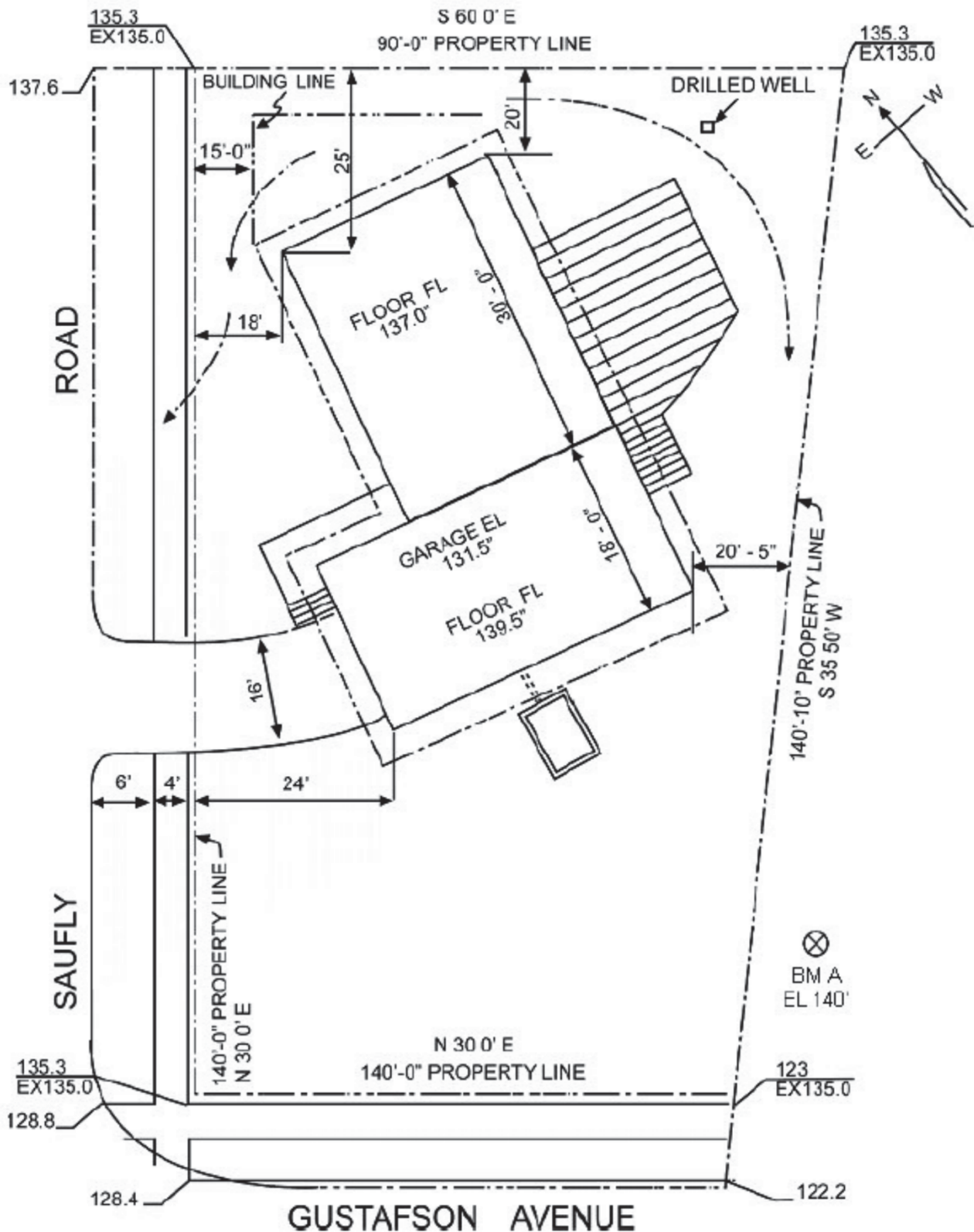
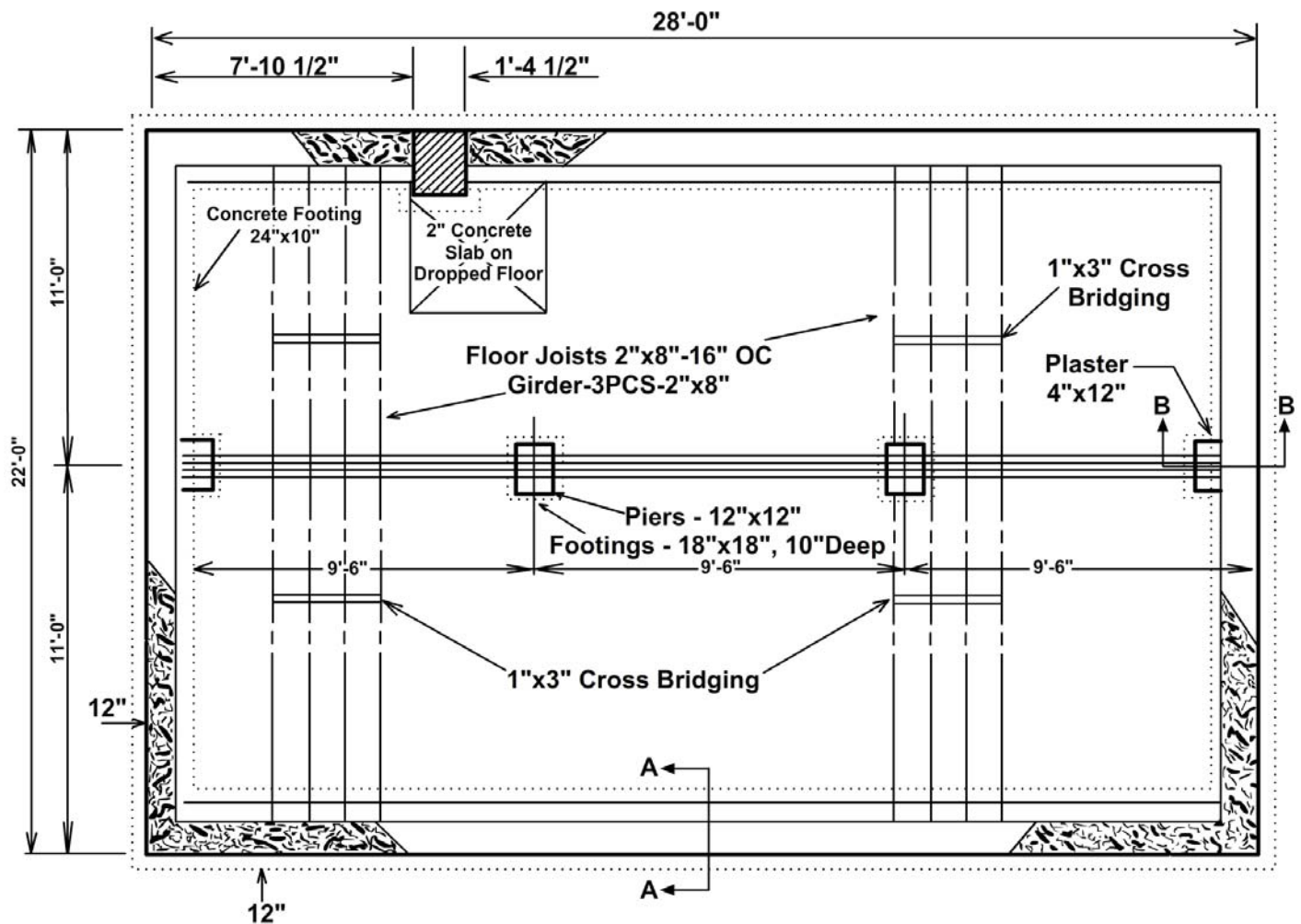


Figure 7-31 — Plot plan.



## Foundation Plan

A foundation plan is a plane view of a structure. That is, it looks as if it were projected onto a horizontal plane and passed through the structure. In the case of the foundation plan, the plane is slightly below the level of the top of the foundation wall. The plan in *Figure 7-32* shows that the main foundation consists of 12 inch and 8 inch concrete masonry unit (CMU) walls measuring 28 feet lengthwise and 22 feet crosswise. The lower portion of each lengthwise section of wall is to be 12 inches thick to provide a concrete ledge 4 inches wide.



**Figure 7-32 — Foundation plan.**

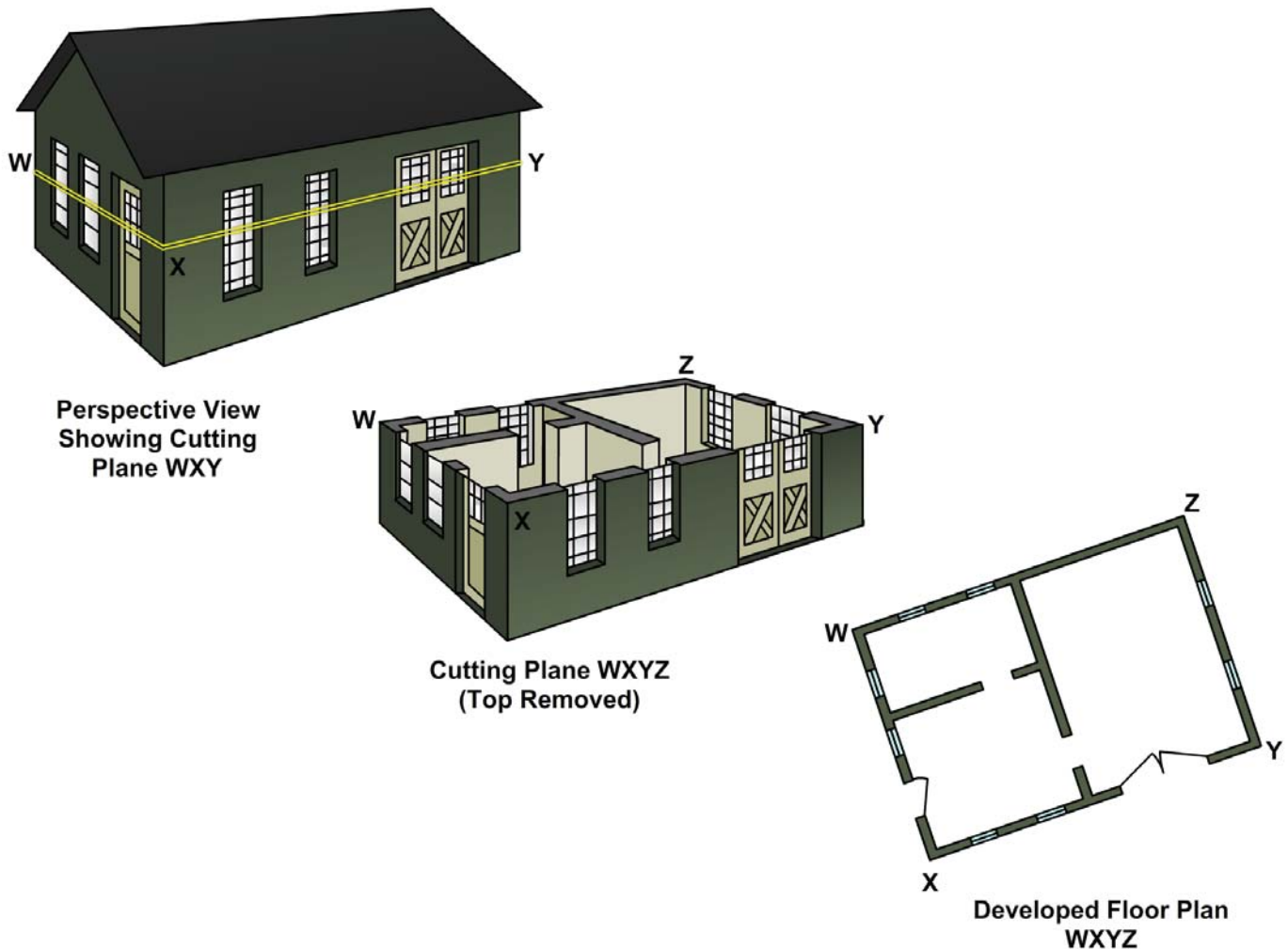
A girder running through the center of the building will be supported at the ends by two 4 by 12 inch concrete pilasters butting against the end foundation walls. Intermediate support for the girder will be provided by two 12 by 12 inch concrete piers, each supported on 18 by 18 inch spread footings, which are 10 inches deep. The dotted lines around the foundation walls indicate that these walls will also rest on spread footings.

## Floor Plan

Floor plans are views of a building as though cutting planes were made through the building horizontally. The cutting plane is generally taken 5 feet 0 inches above the floor being shown.

The way a floor plan is developed from elevation, to cutting plane, to floor plan is depicted in *Figure 7-33*. An architectural or structural floor plan shows the structural characteristics of the building at the level of the plane of projection. A mechanical floor plan shows the plumbing and heating systems and

any other mechanical components other than those that are electrical. An electrical floor plan shows the lighting systems and any other electrical systems.



**Figure 7-33 — Typical floor plan.**

### Framing Plan

The floor framing plan (*Figure 7-34*) is a plan view of the layout of girders, beams, and joists. Joists and double framing are drawn in the position they will occupy in the completed building. Joists do not need dimensions at every location. Notes provide the necessary information, in this case “2” by 8” joists at 16 inches on center (O.C.).

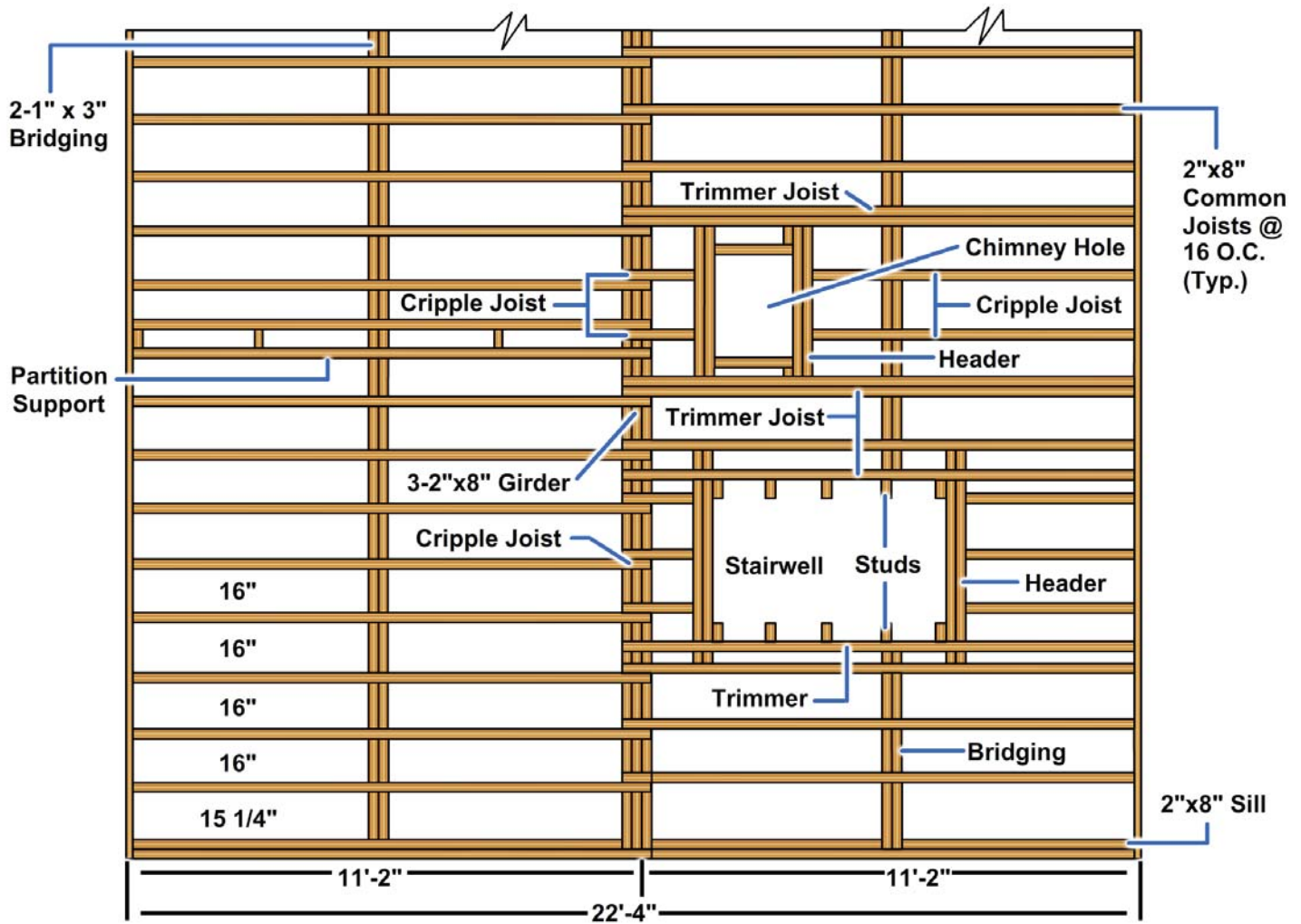
Bridging is also drawn in position perpendicular to the joist but called out by note as “2- 1” x 3” bridging”. The span of the joist controls the number of required rows of cross bridging. The rows should not be more than 7 or 8 feet apart. Hence, a 14 foot span may need only one row of bridging, but a 16 foot span needs two rows. Notes also identify floor openings, trimmers, plates, or doubles to support heavier floor loads.

Floor framing plans do not indicate length dimensions for individual pieces. The builder is able to determine those from overall building dimensions, dimensions for each bay, or distances between columns or posts.

Wall framing plans (*Figure 7-35*) show the location and method of framing openings and ceiling heights so that studs and posts can be cut. Since it is a view on a vertical plane, a wall framing plan is



not a plan in the strict technical sense. However, the practice of calling it a plan has become a general custom.



**Figure 7-34 — Floor framing plan.**

Roof framing plans for wood frame construction are drawn in the same manner as the floor framing plan. The rafters are shown in the same manner as joists, with rafters shown spanning the building and supporting the roof.

A utility plan is a floor plan that shows the layout of heating, electrical, plumbing, or other utility systems. Utility plans are used primarily by the ratings responsible for the utilities, and are equally important to the builder. Most utility installations require that openings be left in walls, floors, and roofs for the admission or installation of utility features. The builder who is placing a concrete foundation wall must study the utility plans to determine the number, sizes, and locations of openings he or she must leave for utilities.

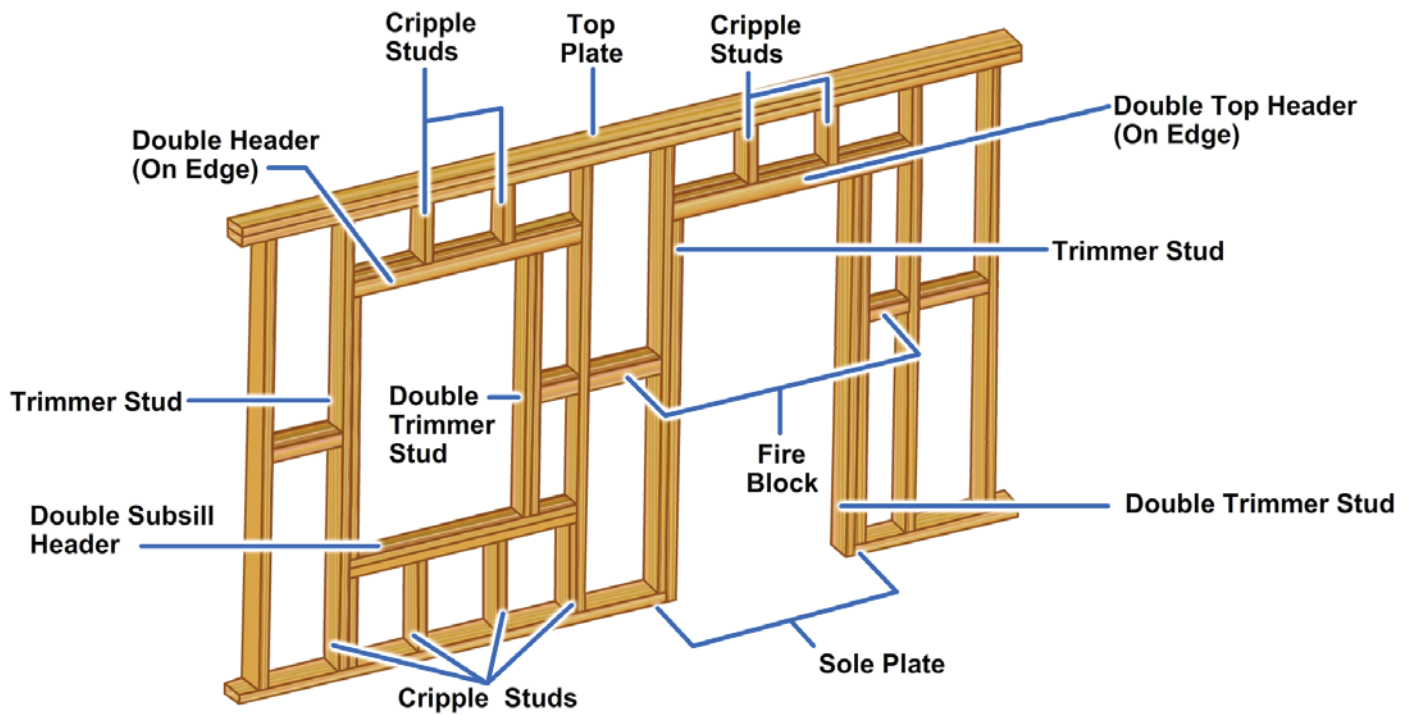


Figure 7-35 — Wall framing plans.

## Elevations

Elevations show the front, rear, and sides of a structure, as they would appear projected on vertical planes. Studying the elevation drawing (*Figure 7-36*) gives you a working idea of the appearance and layout of the structure.

Notice that the wall surfaces of this house will consist of brick and the roof covering of composition shingles. The top of the rafter plate will be 8 feet 2 1/4 inches above the level of the finished first floor, and the tops of the finished door and window openings 7 feet 1 3/4 inches above the same level. The roof will be a gable roof with 4 inches of rise for every 12 inches length. Each window shown in the elevations is identified by a capital letter that goes with a window schedule.

## Detail Drawings

### Sectional Views

Sectional views, or sections, provide important information about the height, materials, fastening and support systems, and concealed features of a structure. The initial development of a section and how a structure looks when cut vertically by a cutting plane is shown *Figure 7-37*. The cutting plane is not necessarily continuous, but, as with the horizontal cutting plane in building plans, may be staggered to include as much construction information as possible. Like elevations, sectional views are vertical projections. They are also detail drawings drawn to large scale. This aids in reading, and provides information that cannot be given on elevation or plan views. Sections are classified as typical and specific.

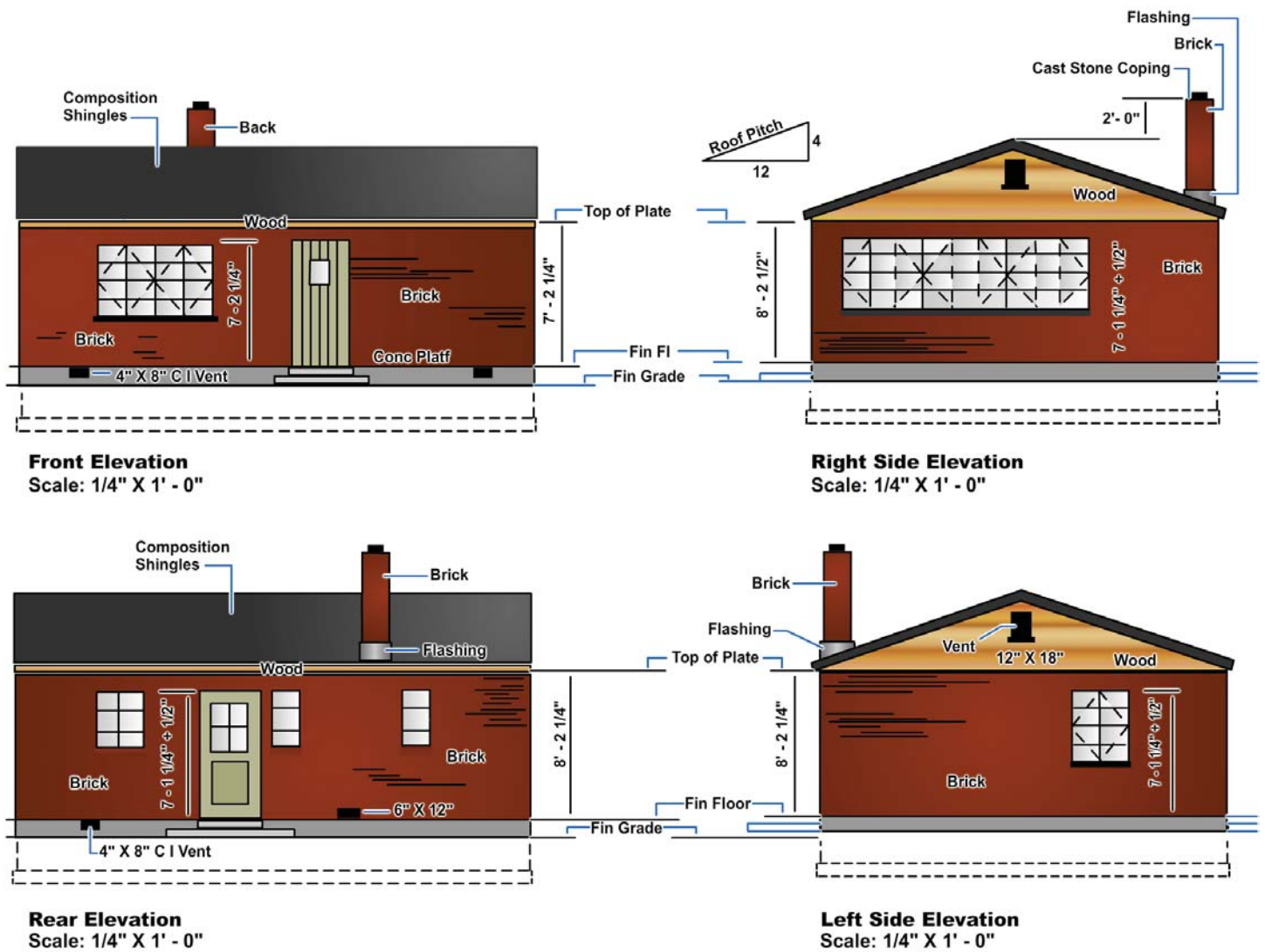
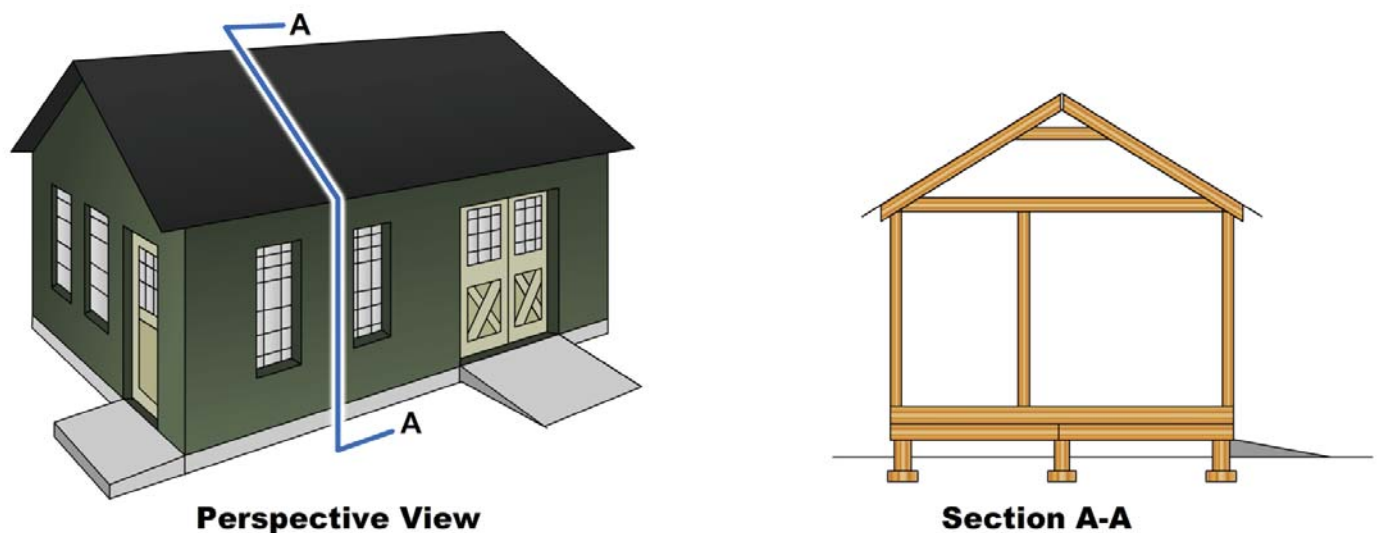


Figure 7-36 — Elevations.

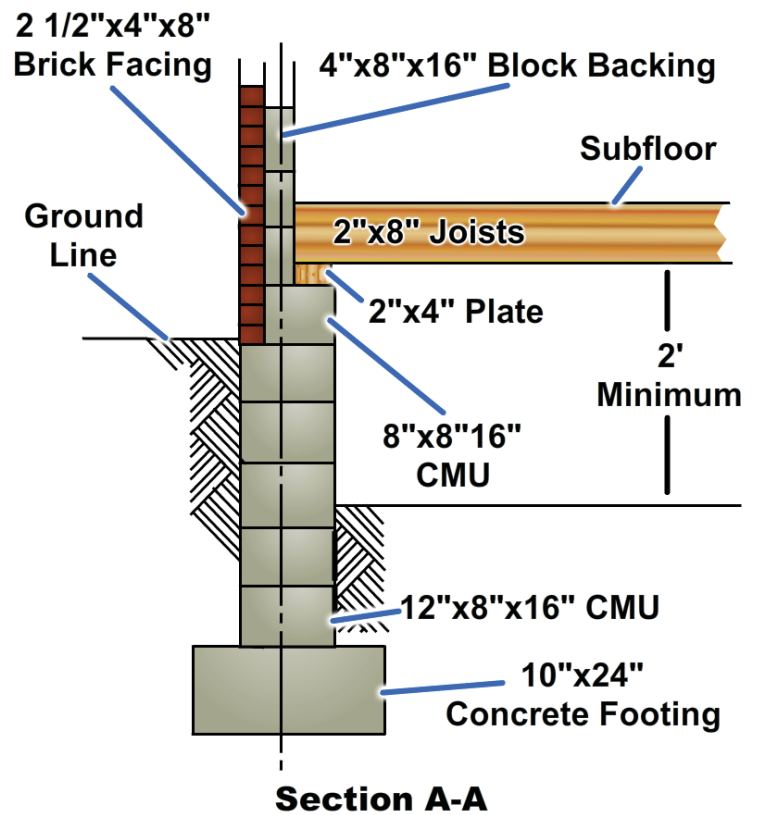


Typical Small Building Showing Cutting Plane A-A And Section Developed From The Cutting Plane

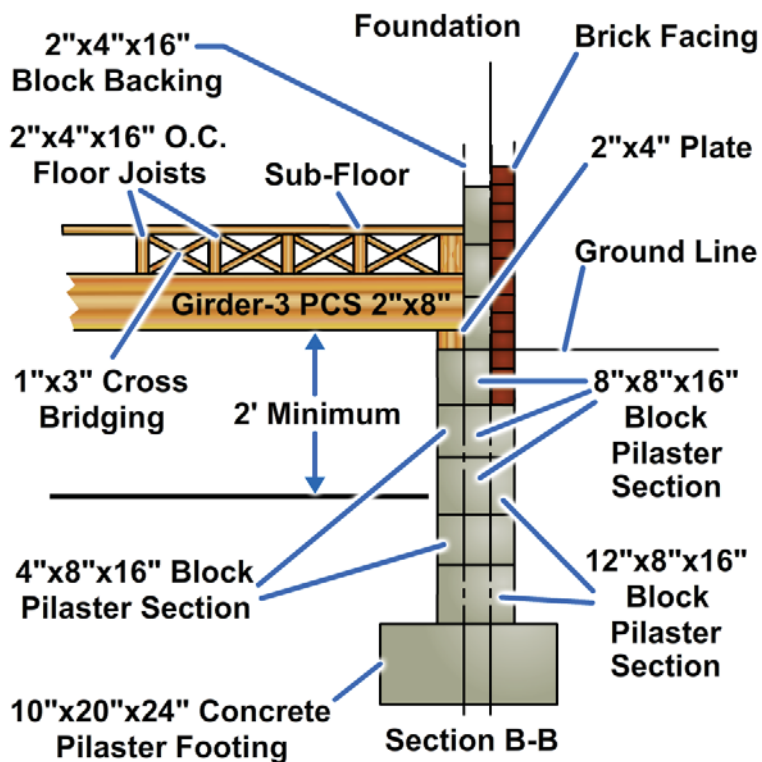
Figure 7-37 — Development of a sectional view.

Typical sections (*Figure 7-38*) represent the average condition throughout a structure and are used when construction features are repeated many times. You can see that it gives a great deal of information necessary for those constructing the building.

The foundation plan shown in *Figure 7-32* specifies that the main foundation of this structure will consist of a 22 by 28 foot concrete block rectangle. In *Figure 7-38*, the section A-A of the foundation plan shows that the front and rear portions of the foundation (28 foot measurements) are made of 12 by 8 by 16 inch CMUs centered on a 10 by 24 inch concrete footing to an unspecified height. These are followed by 8 inch CMUs, which form a 4 inch ledger for floor joist support on top of the 12 inch units. In this arrangement, the 8 inch CMUs serve to form a 4 inch support for the brick. The main wall is then laid with standard 2 1/2 by 4 by 8 inch face brick backed by 4 by 8 by 16 inch CMUs.



**Figure 7-38 — Typical section of a masonry building.**



**Figure 7-39 — Specific section of a concrete masonry wall.**

Section B-B, shown in *Figure 7-39* of the foundation plan, shows that both side walls (22 foot measurements) are 8 inches thick centered on a 24 inch concrete footing to an unspecified height. It also illustrates the pilaster, a specific section of the wall to be constructed for support of the girder. It shows that the pilaster is constructed of 12 by 8 by 16 inch CMUs alternated with 4 by 8 by 16 inch and 8 by 8 by 16 inch CMUs. The hidden lines (dashed lines) on the 12 inch wide units indicate that the thickness of the wall beyond the pilaster is 8 inches. Notice how the extra 4 inch thickness of the pilaster provides a center support for the girder, which will support the floor joists.

### Detail Views

Detail views are large-scale drawings of construction assemblies and installations that cannot be clearly shown in the sections. These enlarged drawings show the various parts in more detail and how they will be connected and placed.

The scale depends on how large the drawing needs to be magnified to explain the required information clearly. Details are usually drawn at a larger scale than the sections, generally 1-, 1 1/2-, or 3-inch = 1 foot.

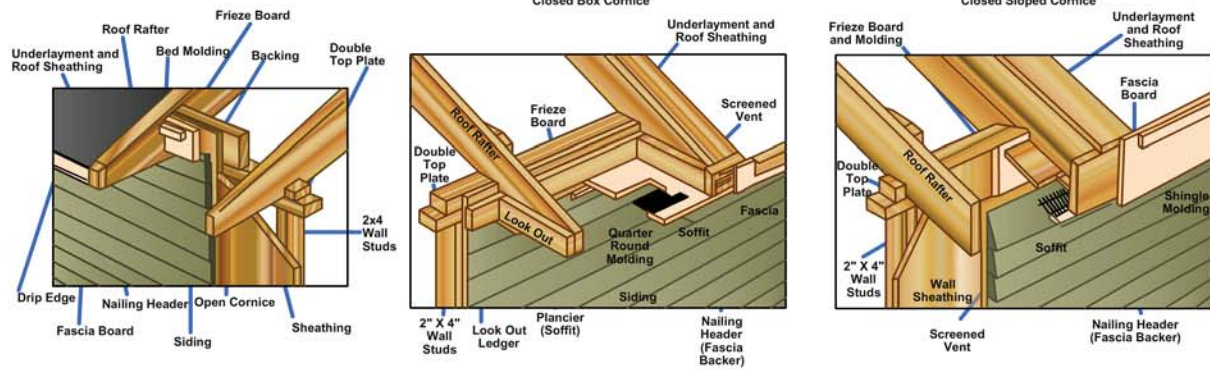
Architectural drawing standards contain details commonly used for installation of items such as doorframes, window frames, fireproofing, and material connections; they do, however, need to be adapted to the particular building being drawn. When different conditions actually exist, avoid the use of “typical” details; they will be misleading and cause confusion. The designer needs to understand construction well enough to make accurate detail drawings for each unique situation.

Details are commonly used for some specific phases and elements of construction such as foundations, doors, windows, cornices, and so forth (*Figure 7-40*). Show their details with the applicable main division of construction drawings and group them so that references can be made easily from the general drawing.

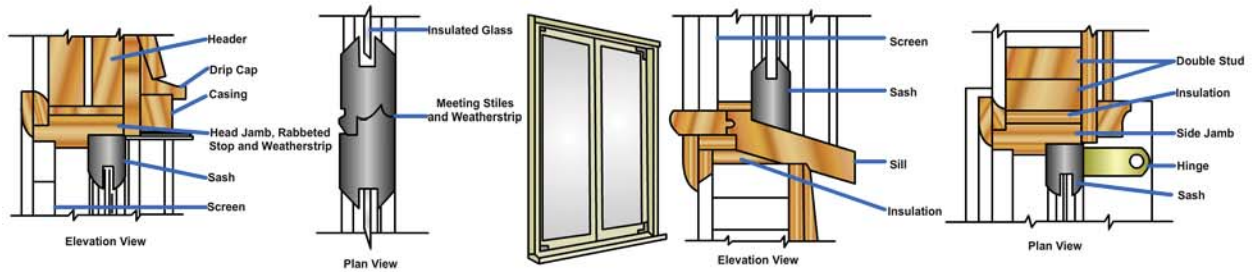
Use architectural symbols (*Figure 7-41*) to provide reference locations for doors and windows in general, sectional, and detail drawings.



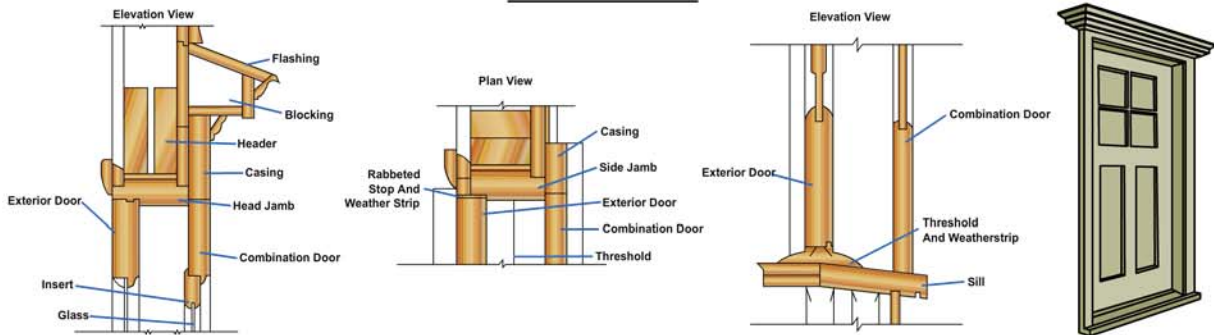
## Typical Cornice Details



## Detail of Window



## Detail of Door



## Typical Sill Details

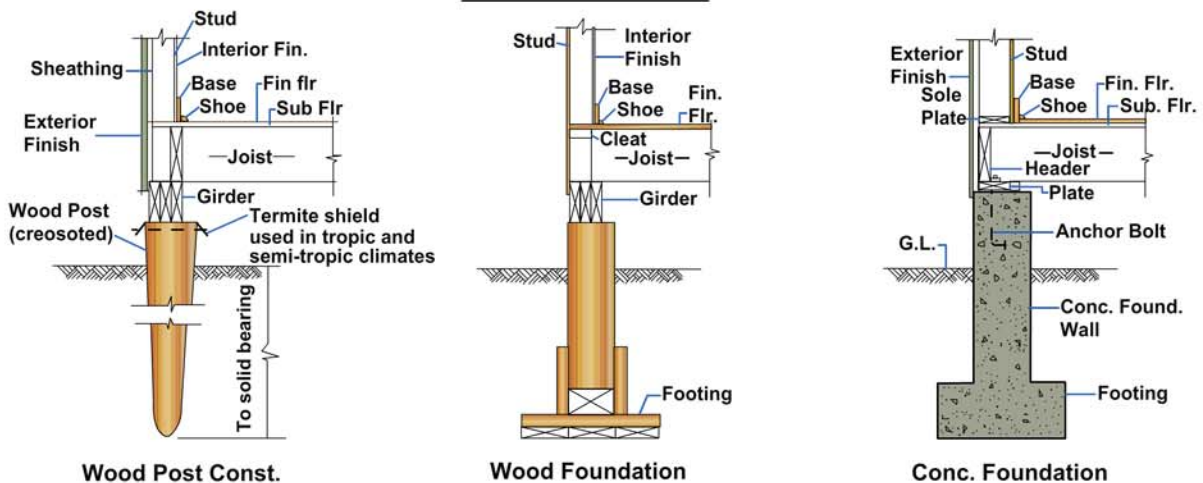
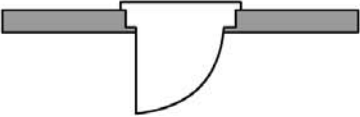
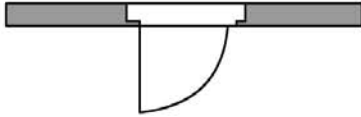
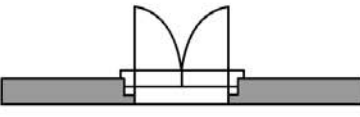
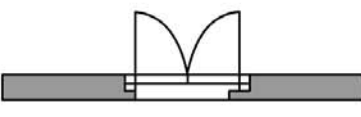
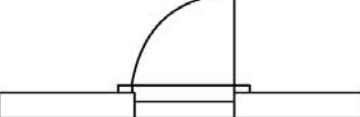
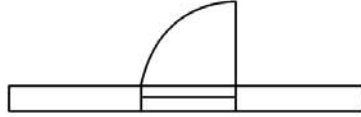
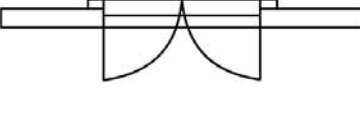
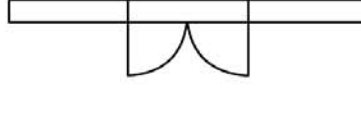
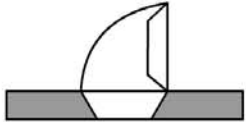


Figure 7-40 — Example of detail grouping.

## Door Symbols

| Type                                                    | Symbol                                                                             |                                                                                     |
|---------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Single-swing with threshold<br>in extended masonry wall |  |  |
| Single door, opening in                                 |  |  |
| Double door, opening out                                |  |  |
| Single-swing with threshold<br>in exterior frame wall   |  |  |
| Single door, opening out                                |  |  |
| Double door, opening in                                 |                                                                                    |                                                                                     |
| Refrigerator door                                       |  |                                                                                     |

## Window Symbols

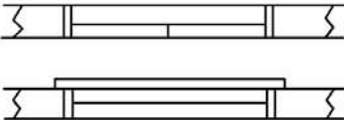
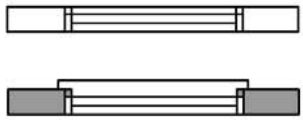
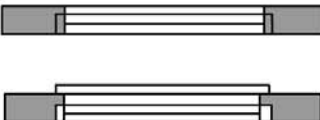
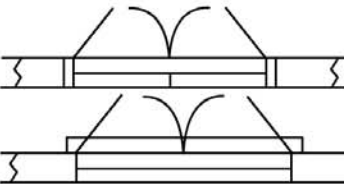
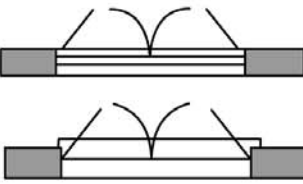
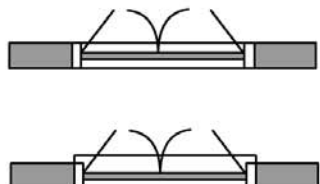
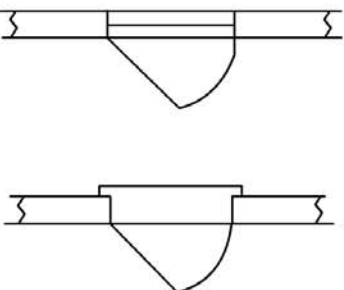
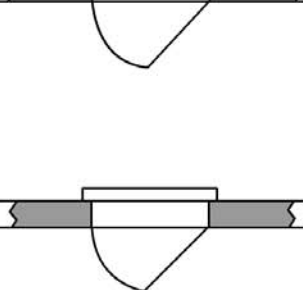
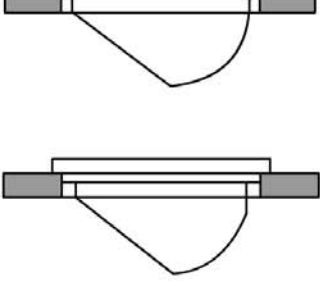
| Type                                 | Wood or metal<br>sash in frame wall                                                 | Metal sash in<br>masonry wall                                                        | Wood sash in<br>masonry wall                                                          |
|--------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Double<br>hung                       |  |  |  |
| Casement -<br>Double,<br>opening out |  |  |  |
| Casement -<br>Single,<br>opening in  |  |  |  |

Figure 7-41 — Common architectural symbols for doors and windows.

## Specifications

Because many aspects of construction cannot be shown graphically, even the best prepared construction drawings often inadequately show some portions of a project. For example, how can anyone show on a drawing the quality of workmanship required for the installation of doors and windows? Or, who is responsible for supplying the materials? These are things that can be conveyed only by hand lettered notes. The standard procedure is to supplement construction drawings with detailed written instructions. These written instructions, called specifications, or more commonly specs, define and limit materials and fabrication to the intent of the engineer or designer.

The drawings, together with the project specifications, define the project in detail and show exactly how to construct it. Usually, drawings for an important project are accompanied by a set of project specifications. The drawings and project specifications are inseparable. Drawings indicate what the project specifications do not cover. Project specifications indicate what the drawings do not portray, or they further clarify details that are not covered amply by the drawings and notes on the drawings. When you are preparing project specifications, it is important that you closely coordinate the specifications and drawings in order to minimize discrepancies and ambiguities.

When preparing drawings, you will need to be familiar with the general format and terminology used in the specifications. After the last specification, list the definitions of the terms used. Certain routine declarations of responsibility and certain conditions to be maintained on the job may accompany the specifications. A flow chart for selection and documentation of concrete proportions is illustrated in *Figure 7-42*.

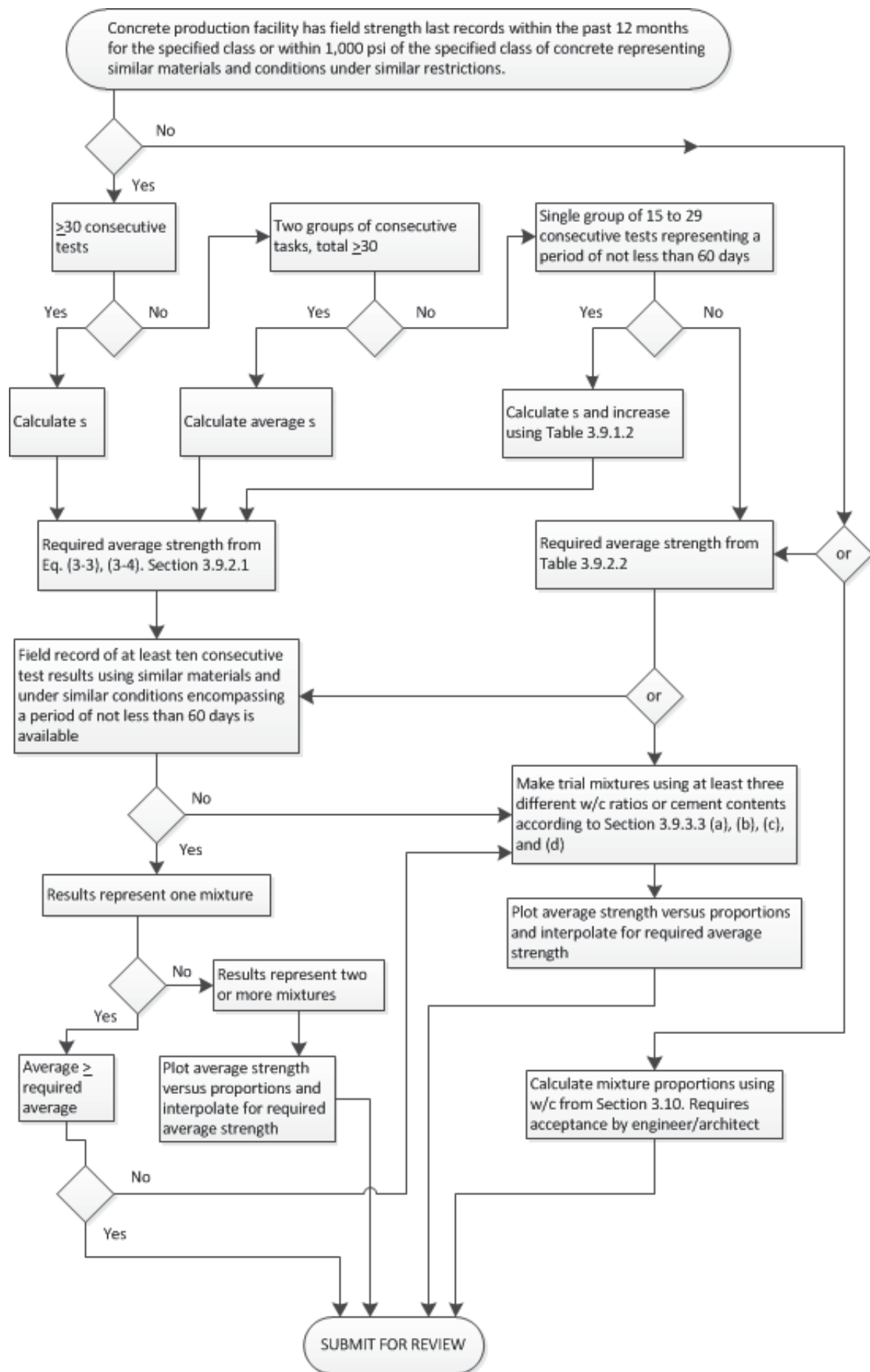


Figure 7-42 — Flow Chart for selection and documentation of concrete proportions.

## End of Chapter 7

### Structural and Architectural Drawings

#### Review Questions

- 7-1. Which of the following techniques is used to create the architect's concept of a building, ship, or aircraft?
- A. Isometric view
  - B. Orthographic projection
  - C. Pictorial drawing
  - D. Revolved view
- 7-2. What document provides common symbols used in an architectural drawing?
- A. ASME Y41.3.4
  - B. ASTM F3000-1D
  - C. IEEE 101G
  - D. MIL-STD-18B
- 7-3. Which of the following types of shapes are the most common structural members?
- A. A, C, and H
  - B. A, S, and W
  - C. C, H, and J
  - D. C, S, and W
- 7-4. Which of the following symbols is used to identify wide-flange steel beams?
- A. W
  - B. HP
  - C. S
  - D. C
- 7-5. Which of the following symbols is used to identify a bearing pile?
- A. W
  - B. HP
  - C. S
  - D. C
- 7-6. Which of the following types of angle shapes are most commonly used?
- A. Acute and obtuse angles
  - B. Equal-leg and acute angle
  - C. Equal-leg and unequal-leg
  - D. Obtuse and unequal-leg



- 7-7. In dimensioning, the structural tee symbol is preceded by what letters?
- A. HP
  - B. HT
  - C. PL
  - D. ST
- 7-8. What component is the primary horizontal member of a steel frame structure?
- A. Pillar
  - B. Girder
  - C. Flat bar
  - D. Column
- 7-9. Which of the following terms is the total weight of a structure?
- A. Load bearing capacity
  - B. Structural integrity
  - C. Total dead load
  - D. Total live load
- 7-10. Which of the following supplementary symbols is used to identify a flush contour?
- A. Circle
  - B. Flag
  - C. Line
  - D. Square
- 7-11. On a finish symbol, what letter indicates chipping method of finishing?
- A. C
  - B. F
  - C. G
  - D. M
- 7-12. Which of the following supplementary symbols is used to identify weld all around?
- A. Circle
  - B. Flag
  - C. Line
  - D. Square
- 7-13. Which of the following types of drawings provide important details, such as the nature of the underlying soil and location of adjacent structures?
- A. Erection
  - B. Fabrication
  - C. Falsework
  - D. Layout

- 7-14. Layout drawings are supplemented by instructions and information known as what?
- A. General notes
  - B. Modifications
  - C. References
  - D. Specifications
- 7-15. A general plan contains information on the size, material and makeup of what components in a structure?
- A. Main members
  - B. Preliminary structures
  - C. Surrounding structures
  - D. Temporary members
- 7-16. Which of the following types of drawings contains necessary information on the size, shape, material, and provisions for connections and attachments for each member?
- A. Erection
  - B. Fabrication
  - C. Falsework
  - D. Layout
- 7-17. Which of the following types of drawings shows the location and position of the various members in the finished structure?
- A. Erection
  - B. Fabrication
  - C. Falsework
  - D. Layout
- 7-18. Which of the following types of drawings refers to temporary supports of timber or steel required in the erection of difficult structures?
- A. Erection
  - B. Fabrication
  - C. Falsework
  - D. Layout
- 7-19. Most construction drawings consist of what type of view?
- A. Isometric view
  - B. Orthographic projection
  - C. Pictorial drawing
  - D. Revolved view

- 7-20. The most common construction plans are site, plot, foundation, and which other type of plan?
- A. Falsework
  - B. Framing
  - C. Phase
  - D. Supplementary
- 7-21. A site plan shows contours, boundaries, roads, and what other feature?
- A. Attachment of other parts of a structure
  - B. Bench marks
  - C. Concealed features of a structure
  - D. Utilities
- 7-22. Which construction plan is used to set up corners and perimeters of the building using batter boards and stakes?
- A. Plot
  - B. Site
  - C. Floor
  - D. Foundation
- 7-23. At what distance above the floor being shown is the cutting plane of a floor plan generally taken?
- A. 4 feet 0 inches
  - B. 4 feet 6 inches
  - C. 5 feet 0 inches
  - D. 5 feet 6 inches
- 7-24. A sectional view provides important information about the height, materials, and what other feature in a drawing?
- A. Utilities
  - B. Concealed features of a structure
  - C. Bench marks
  - D. Attachment of other parts of a structure
- 7-25. Concerning detail views, which of the following is true?
- A. Enlarged drawings to show various parts in more detail
  - B. Exploded view of a part for location of finish marks
  - C. Highlighted drawing to show importance
  - D. Reduced drawings to show insignificance

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(Optional) Correction

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## CHAPTER 8

### DEVELOPMENTS AND INTERSECTIONS

Sheet metal drawings are also known as sheet metal developments and pattern drawings, and we may use all three terms in this chapter. These terms are used because the layout, when made on heavy cardboard, thin metal, or wood, is often used as a pattern to trace the developed shape on flat material. These drawings are used to construct various sheet metal items, such as ducts for heating, ventilation, and air-conditioning systems; flashing, valleys, and downspouts in buildings; and parts on boats, ships, and aircraft.

A sheet metal development serves to open up an object that has been rolled, folded, or a combination of both, and makes that object appear to be spread out on a plane or flat surface. Sheet metal layout drawings are based on three types of development: parallel, radial, and triangulation.

The most common method to create simple sheet metal development drawings is by manual drafting and sketching methods. Sheet metal drafting/sketching templates are designed to facilitate layouts of sheet metal air conditioning and heating conduits and are available from manufacturers like Rapidesign®, Pickett®, Staedtler-Mars®, and Timely®. Computer-aided drafting (CAD) accelerates the sheet metal development design and template drawing process. CAD enables designer the flexibility to work with any CAD data to create, edit, and prepare models for high precision sheet metal fabrication. Sheet metal development CAD programs may be standalone software packages or add-on packages to powerful CAD applications such as AutoCAD®.

### LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Recognize sheet metal developments.
2. Recognize the differences among parallel developments.
3. Recognize the differences among radial developments.
4. Recognize the differences among triangular developments.

### SEAMS, JOINTS, AND EDGES

A development of an object that will be made of thin metal, such as a duct or part of an aircraft skin, must include consideration of the developed surfaces, the joining of the edges of these surfaces, and the exposed edges. The drawing must allow for the additional material needed for those seams, joints, and edges.

A variety of ways to illustrate seams, joints, and edges are shown in *Figures 8-1 through 8-3*. Seams are used to join edges. The seams may be fastened together by seams, solder, rivets, adhesive, or welds. Exposed edges are folded or wired to give the edges added strength and to eliminate sharp edges.



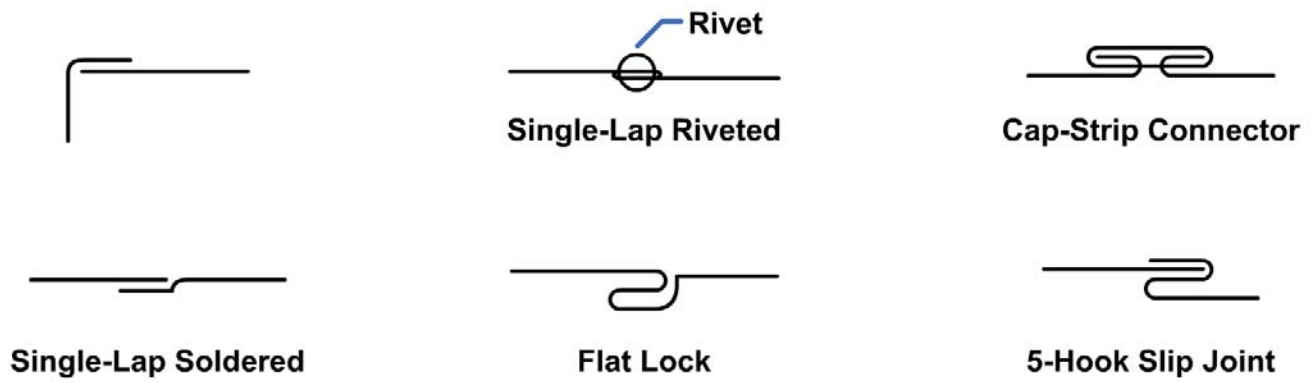


Figure 8-1 — Seams.

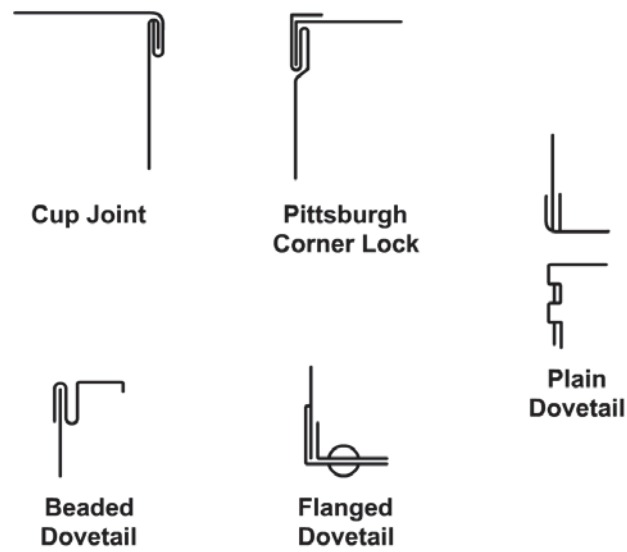


Figure 8-2 — Joints.

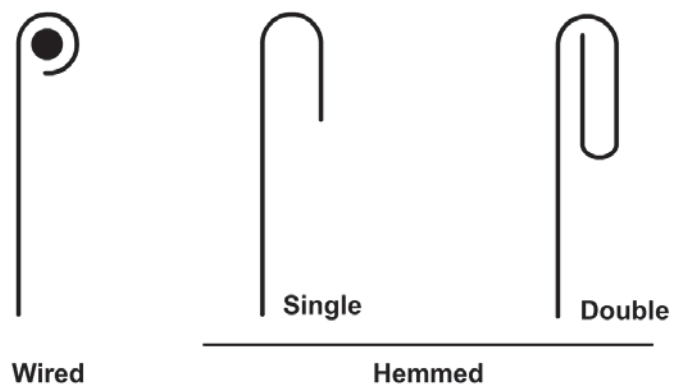


Figure 8-3 — Edges.

There are three types of lap seams: the plain lap seam, the offset lap seam, and the corner lap seam (Figure 8-4). Lap seams can be joined by drilling and riveting, by soldering, or by both riveting and soldering. To figure the allowance for a lap seam, you must first know the diameter of the rivet that you plan to use. The center of the rivet must be set in from the edge a distance of  $2\frac{1}{2}$  times its diameter; therefore, the allowance must be 5 times the diameter of the rivet that you are using.

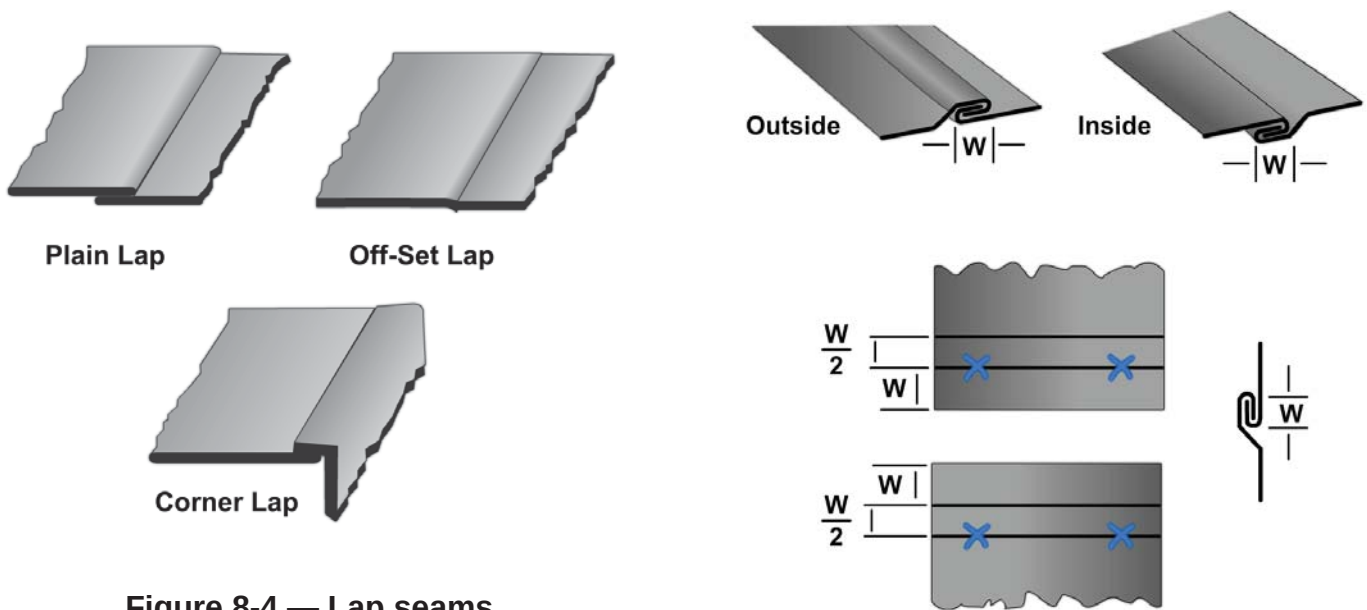


Figure 8-4 — Lap seams.

Figure 8-5 — Grooved seams.

Grooved seams are useful in the fabrication of cylindrical shapes. There are two types of grooved seams: the outside grooved seam and the inside grooved seam (Figure 8-5). The allowance for a grooved seam is three times the width ( $W$ ) of the lock. One-half of the total allowance width is added to each edge. For example, if you are to have a  $\frac{1}{4}$  inch grooved seam,  $3 \times \frac{1}{4} = \frac{3}{4}$  inch, or the total allowance;  $\frac{1}{2}$  of  $\frac{3}{4}$  inch =  $\frac{3}{8}$  inch, or the allowance that you are to add to each edge.

The Pittsburgh lock seam (Figure 8-6) is a corner lock seam. This seam is used as a lengthwise seam at corners of square and rectangular pipes and elbows as well as fittings and ducts.

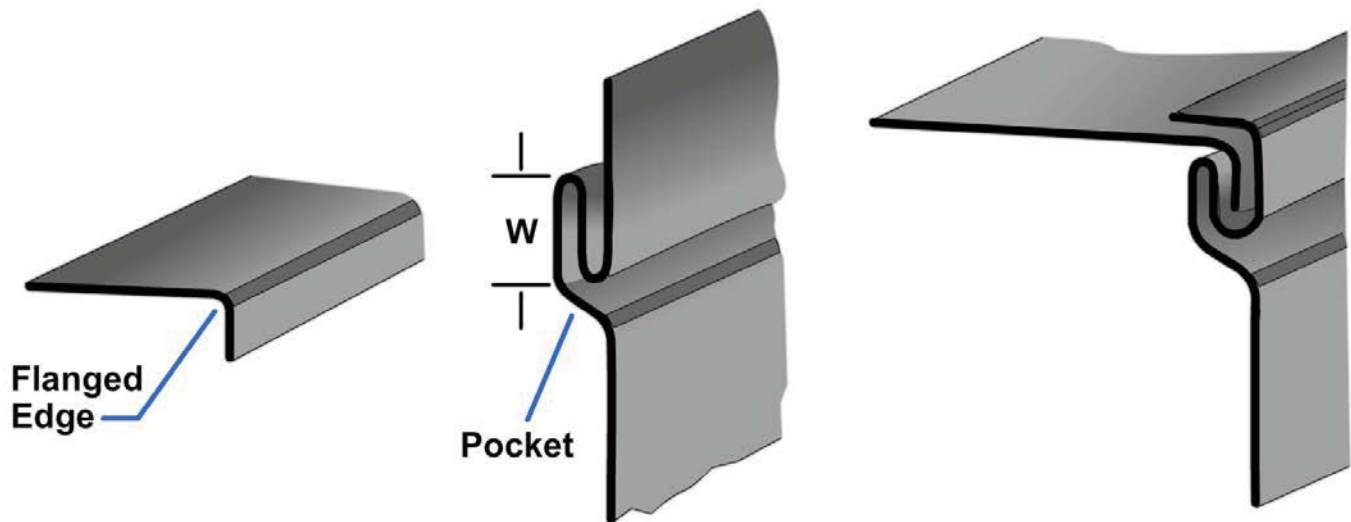


Figure 8-6 — Pittsburgh lock seam.

The Pittsburgh lock seam can be made in a brake but it has proved to be so universal in use that special forming machines have been designed and are available. The lock seam appears to be quite complicated, but like lap and grooved seams, it consists of only two pieces. The two parts are the flanged, or single, edge and the pocket that forms the lock. The pocket is formed when the flanged edge is inserted into the pocket, and the extended edge is turned over the inserted edge to complete the lock.

Note that most of the sheet metal developments illustrated in this chapter do not make any allowances for edges, joints, or seams. However, the designer who lays out a development must add extra metal where needed.

## BENDS

The designer must also show where the material will be bent, and *Figure 8-7* shows several methods used to mark bend lines. If the finished part is not shown with the development, then drawing instructions, such as “bend up 90 degrees,” “bend down 180 degrees,” or “bend up 45 degrees,” should be shown beside each bend line.

When bending metal to exact dimensions, the amount of material needed to form the bend must be known. The term for the amount of material that is actually used in making the bend is known as bend allowance.

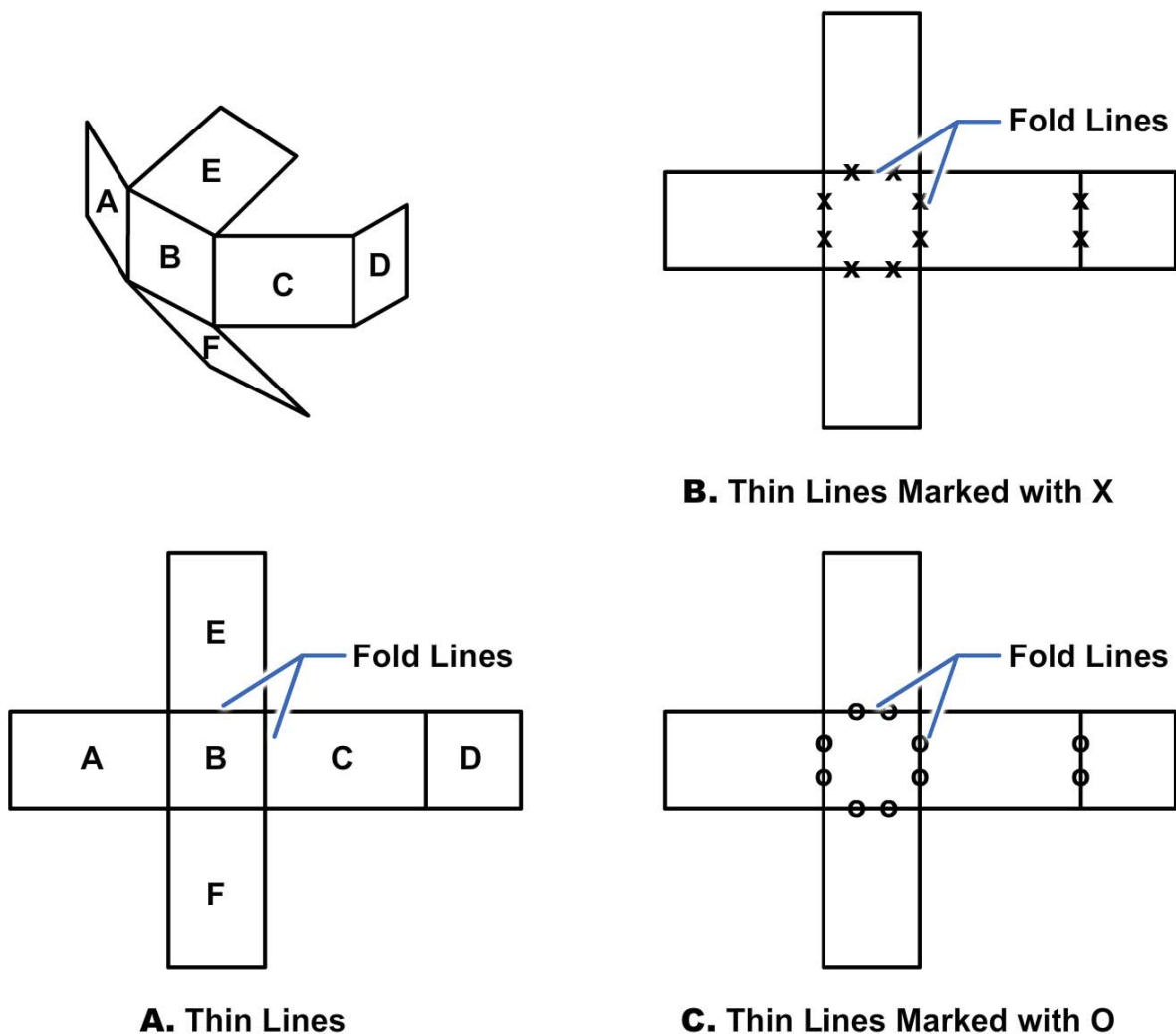


Figure 8-7 — Methods used to identify fold or bend lines.

Bending compresses the metal on the inside of the bend and stretches the metal on the outside of the bend. Approximately halfway between these two extremes lays a space that neither shrinks nor stretches. This space is known as the neutral line or neutral axis (*Figure 8-8*). It is along the neutral axis that bend allowance is computed.

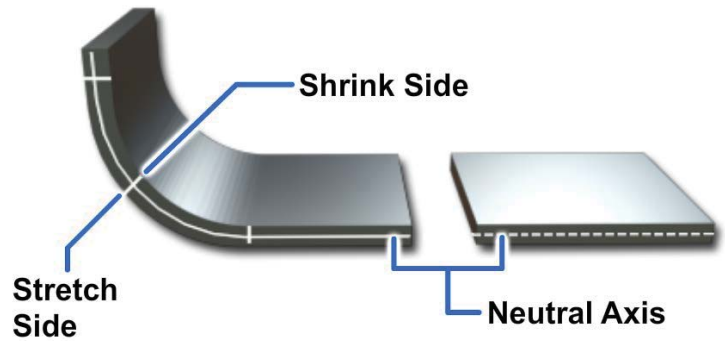


Figure 8-8 — Neutral axis.

## Bend Allowance Terms

It is important to be familiar with the following terms related to a bending job. The bend allowance terminology location is illustrated in *Figure 8-9*.

- Bend allowance—is the amount of material consumed in making a bend.
- Leg—is the longer part of a formed angle.
- Flange—is the shorter part of a formed angle, the opposite of leg. If each side of the angle is the same length, then each is known as a leg.
- Flat—is that flat portion not included in the bend. It is equal to the base measurement minus the setback.
- Base measurement—is the outside dimension of a formed part. Base measurement will be given on the drawing or blueprint, or it may be obtained from the original part.

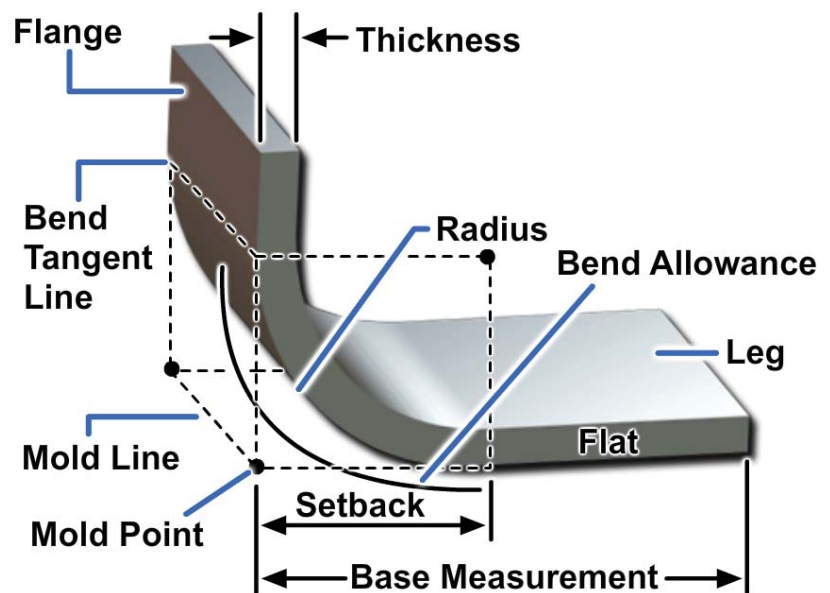


Figure 8-9 — Bend allowance terms.

- Setback (SB)—is the distance from the bend tangent line to the mold point. In a 90-degree bend,  $SB = R + T$  (radius of the bend plus thickness of the metal). The setback dimension must be determined prior to making the bend because setback is used to determine the location of the beginning bend tangent line.
- Radius (R)—of the bend is always to the inside of the metal being formed unless otherwise stated. The minimum allowable radius for bending a given type and thickness of material should always be determined before proceeding with any bend allowance calculations.
- Mold line—is the line formed by extending the outside surfaces of the leg and the flange. (An imaginary point from which real base measurements are provided on drawings.)
- Bend tangent line—is the line at which the metal starts to bend and the line at which the metal stops curving. All the space between the bend tangent lines is the bend allowance.

- K number—is one of 179 numbers on the K chart that corresponds to one of the angles between 0 and 180 degrees to which metal can be bent. When metal is to be bent to any angle other than 90 degrees (K number of 1.0), the corresponding K number is selected from the chart and multiplied by the sum of the radius and the thickness of the metal. The product is the amount of setback for the bend.
- Closed angle—is less than 90 degrees when measured between legs. When the closed angle is 45 degrees, the amount of bend is 180 minus 45 or 135 degrees.
- Open angle—is more than 90 degrees when measured between legs or less than 90 degrees when the amount of bend is measured.

## Bend Allowance Formula

By experimentation with actual bends in metals, aircraft engineers have found that accurate bending results could be obtained by using the following formula for any degree of bend from 1 to 180:

$$(0.0173 \times R + 0.0078 \times T) \times N = BA$$

where

R = the desired bend radius,

T = the thickness of the material, and

N = the number of degrees of bend.

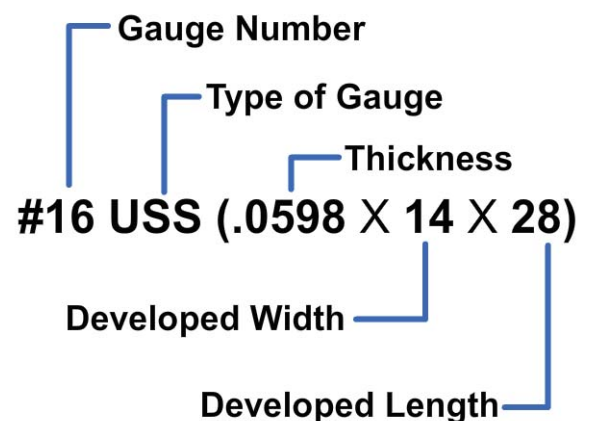
Refer to the General Manual for Structural Repair, Naval Air Systems Command (NAVAIR) manual 01-1A-1, for the appropriate bend allowance tables.

## SHEET METAL SIZES

The thickness of sheet metal is usually specified by the non-linear measure known as its gauge. Thick sheet metal gauge sizes have low gauge numbers, while thinner sheet metal gauge numbers are high. Steel sheet metal sizes from 30 gauge to about 7 gauge are the most commonly used gauges. Gauge differs between iron based metals and non-iron based metals such as copper and aluminum.

There are many different metals that can be made into sheet metal, such as aluminum, brass, copper, steel, tin, nickel, and titanium. For decorative uses, important sheet metals include silver, gold, and platinum (platinum sheet metal is also utilized as a catalyst.)

Metal thicknesses up to 0.25 inch (6 millimeters) are usually designated by a series of gauge numbers. Metal 0.25 inch and over is given in inch and millimeter sizes. In calling for the material size of sheet metal developments, it is customary to give the gauge number, type of gauge, and its inch or millimeter equivalent in brackets followed by the developed width and length in one sheet metal size (*Figure 8-10*). A gauge system is used for carbon steels but not appropriate for stainless steels where thickness is specified in decimals. The USS in *Figure 8-10* identifies the type of gauge system, in this case the United States Standard gauge system.



**Figure 8-10 — Example of a sheet metal size.**

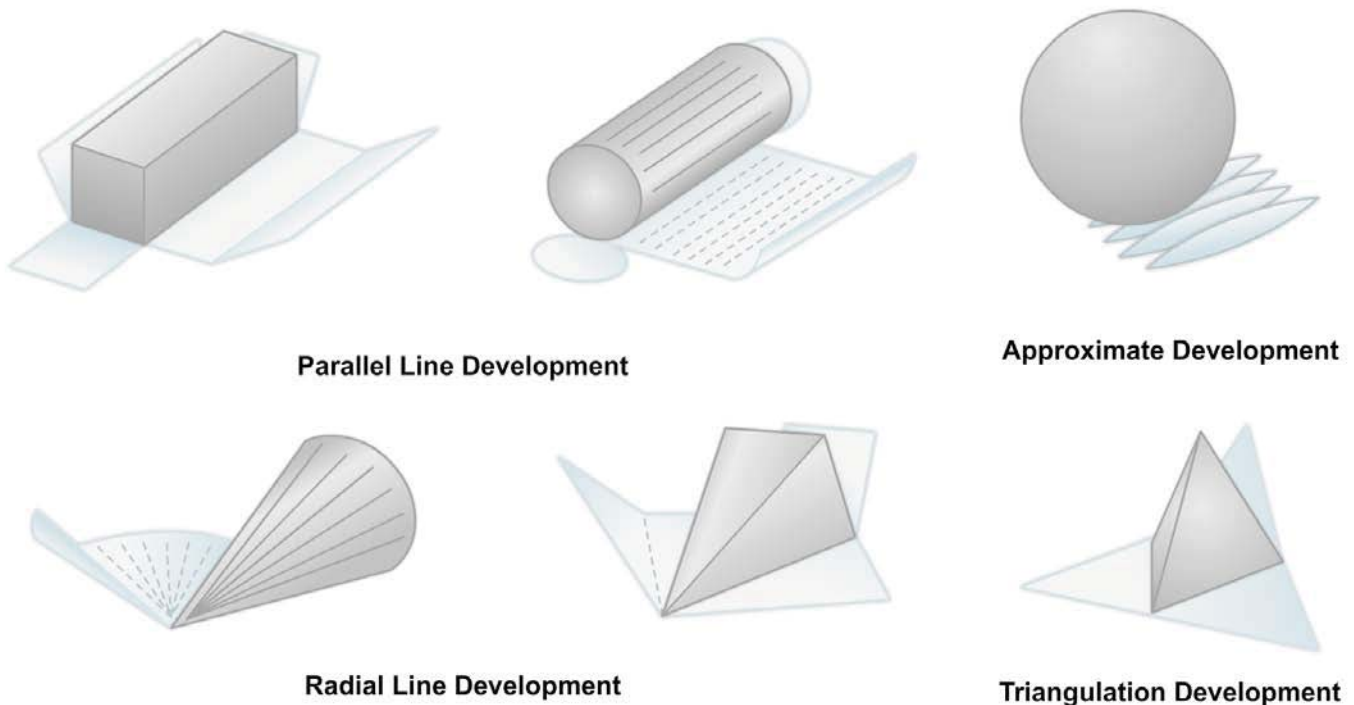


## TYPES OF DEVELOPMENT

A surface is said to be developable if a thin sheet of flexible material, such as paper, can be wrapped smoothly about its surface. Therefore, objects that have plane, flat, or single-curved surfaces are developable. But a surface that is double-curved or warped is not considered developable, and approximate methods must be used to develop it. Typical sheet metal developments are illustrated in *Figure 8-11*.

A spherical shape would be an example of an approximate development. The material would be stretched to compensate for small inaccuracies. For example, the coverings for a football or basketball are made in segments. Each segment is cut to an approximate developed shape, and the segments are then stretched and sewed together to give the desired shape.

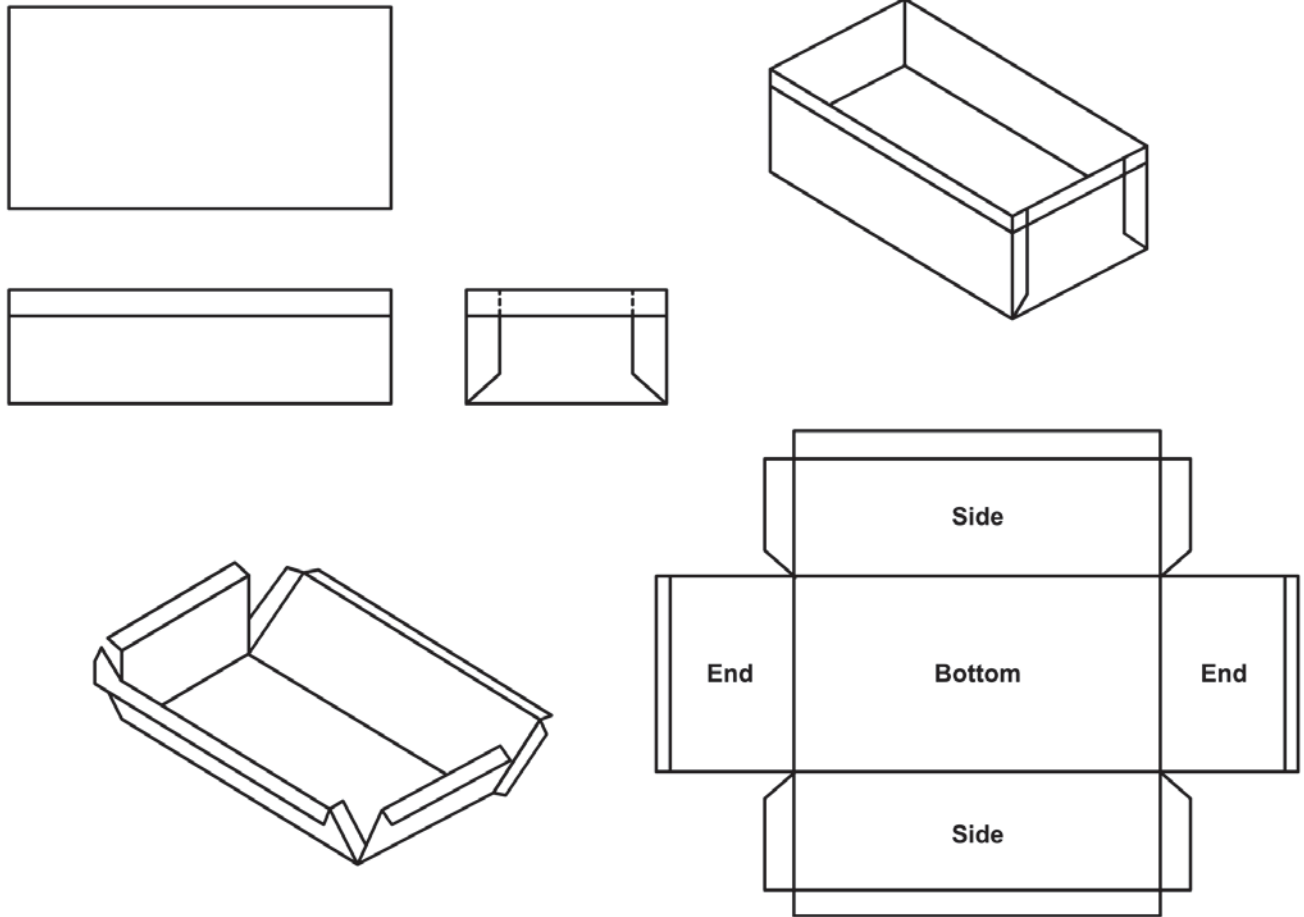
The three procedures commonly used in developing patterns are parallel-line, radial-line, and triangular development.



**Figure 8-11 — Typical sheet metal development.**

### Parallel-Line Development

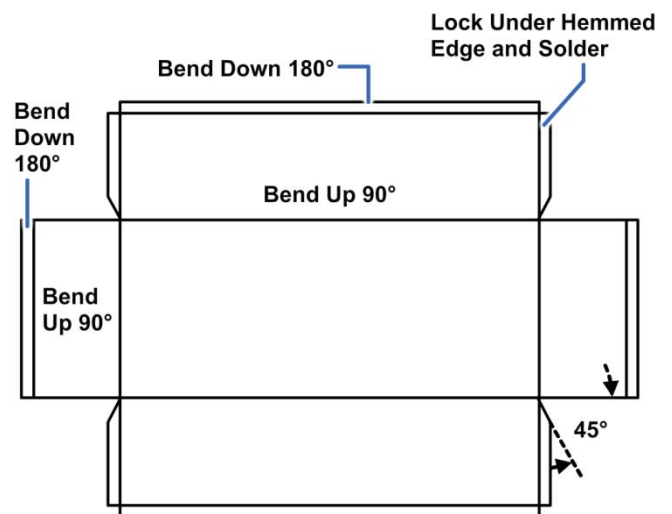
Parallel-line development refers to the development of an object that has surfaces on a flat plane of projection. The true size of each side of the object is known and the sides can be laid out in successive order. The development of a simple rectangular box with a bottom and four sides is illustrated in *Figure 8-12*. There is an allowance for lap seams at the corners and for a folded edge. The fold lines are shown as thin unbroken lines. Note that all lines for each surface are straight.



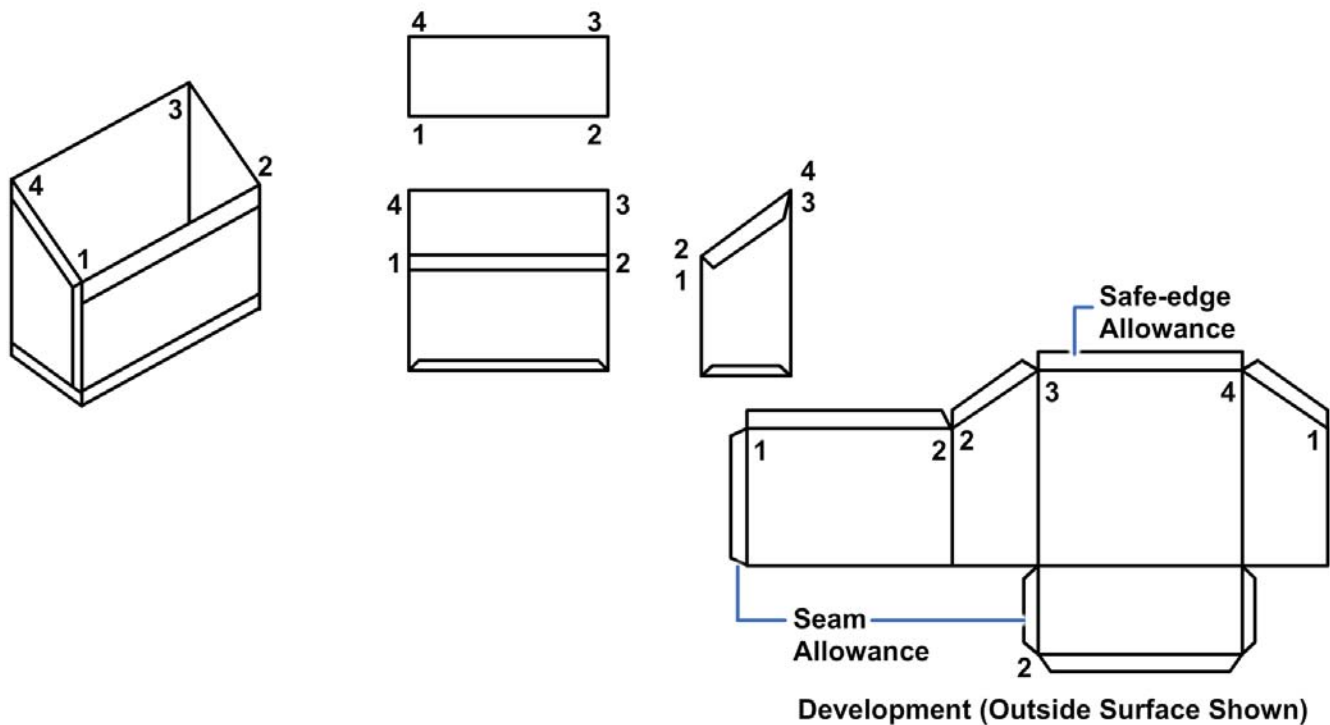
**Figure 8-12 — Development of a rectangular box.**

A parallel-line development drawing may include a complete set of folding instructions as shown in *Figure 8-13*. A letter box development drawing (*Figure 8-14*) illustrates that the back is higher than the front surface.

Parallel-line development is based upon the fact that a line that is parallel to another line is an equal distance from that line at all points. Objects that have opposite lines parallel to each other or that have the same cross-sectional shape throughout their length are developed by this method.



**Figure 8-13 — Development drawing with folding instructions.**



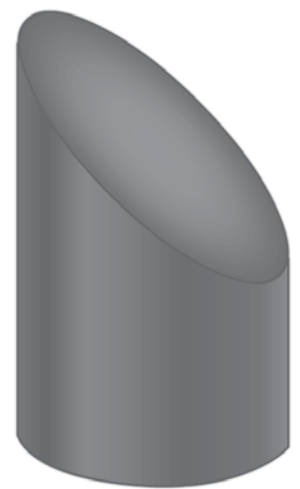
**Figure 8-14 — Development drawing of a letter box.**

### Truncated Cylinder

To gain a clear understanding of the parallel-line method, we will develop a layout of a truncated cylinder (*Figure 8-15*). Such a piece can be used as one half of a two-piece 90-degree elbow.

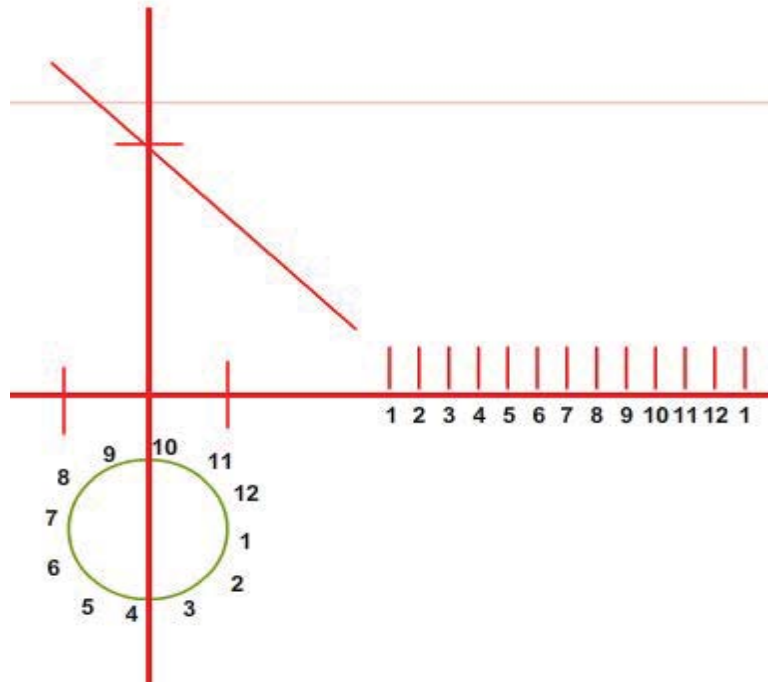
A truncated cylinder is developed in *Figure 8-16*:

1. Mark out reference lines using a set square.
2. Identify the diameter measurement and draw a circle. Here the diameter is 1 1/2 inches (40 millimeters).
3. Use the radius of the circle to divide the circumference into 12 equal sectors.
4. Label the marks 1 to 12. Note the numbers begin on the right-hand side and go in a clockwise direction.
5. Identify and mark the height of the cylinder. Here the height is 2 1/2 inches (60 millimeters).
6. Determine the angle of the top of the cylinder and use a setsquare. Here the angle is 45 degrees.
7. Mark off the radius on both sides of the reference line to construct the sides of the cylinder. Transfer numbers 1 to 12 from the circle to the base of the cylinder. Project these points to the top of the cylinder.
8. Calculate the circumference of the cylinder to determine the stretch out length of the pattern. Use the formula  $C = \pi D$ . The diameter here is 1 1/2 inches (40 millimeters). Mark out the circumference on the horizontal base line.



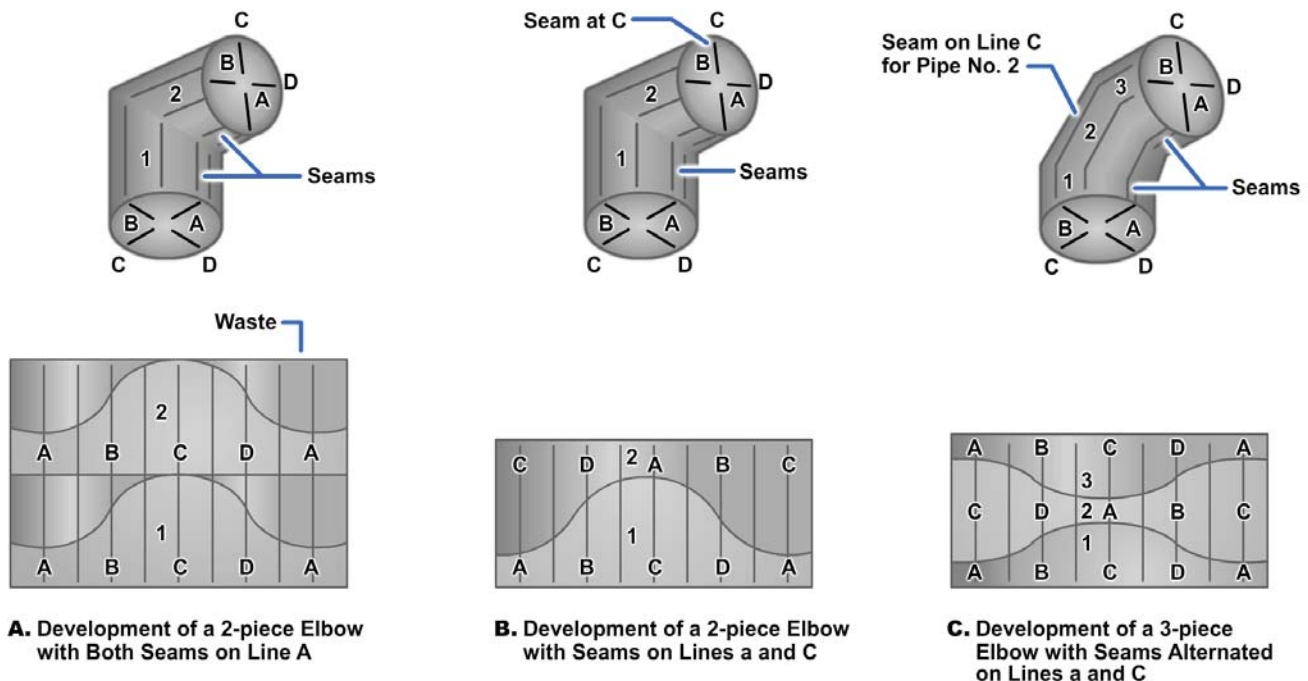
**Figure 8-15 — Truncated cylinder.**

9. Divide the length of the circumference into 12. Draw a reference line and mark on it one-twelfth of the circumference. Use this measurement to set the dividers. Splitting the circumference into halves and quarters reduces tolerance error.
10. Use the dividers to mark the circumference into 12 equal divisions on the base line. Mark these divisions 1 to 12. The final division is numbered 1. Project these divisions upward at 90 degrees.
11. Now develop the stretch out pattern. Transfer the length of the lines on the side view to the corresponding lines on the stretch out. Draw the top line curve of the pattern freehand, by using material like packing cord bent to the curve or by using a flexible curve.
12. This final shape is the stretch out pattern of the cylindrical shape and can be cut to shape to use as a template.



**Figure 8-16 — Truncated cylinder development.**

When the development is finished, the machinist will cut out the pattern. It is normal practice in sheet metal work to place the seam on the shortest side. However, in the development of elbows, the practice would result in considerable waste of material, as shown in *Figure 8-17, view A*. To avoid the waste and to simplify cutting the pieces, the seams are alternately placed 180 degrees apart, as shown in *Figure 8-17, view B* for a two-piece elbow, and *view C* for a three-piece elbow.



**Figure 8-17 — Location of seams on elbows.**

## Radial-Line Development

In radial-line development, the slanting lines of pyramids and cones do not always appear in their true lengths in an orthographic view; the designer must find other means to depict them.

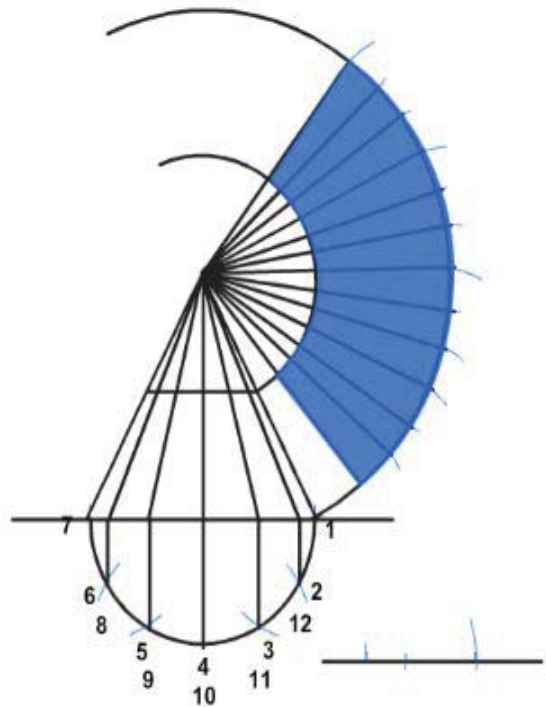
The radial-line method is similar in some respects to the parallel-line method. Evenly spaced reference lines are necessary in both of these methods. However, in parallel-line development, the reference lines are parallel—like a picket fence. In radial-line development, the reference lines radiate from the apex of a cone—like the spokes of a wheel.

The reference lines in parallel-line development project horizontally. In radial-line development, the reference lines are transferred from the front view to the development with the dividers.

Developing a pattern for the frustum of a right cone is a typical practice project that will help you get the feel of the radial-line method. You are familiar with the shape of a cone. A right cone is one that, if set flat side down on a flat surface, would stand straight up. In other words, a centerline drawn from the point, or vertex, to the base line would form a right angle with that line. The frustum of a cone is that part that remains after the point, or top, has been removed.

The procedure for developing a frustum of a right cone is given below. Check each step of the procedure against the development shown in *Figure 8-18*.

1. First establish the apex point (H).
2. Draw reference lines using a set square. Mark out the measurements of the:
  - a. Base (D) – 2 3/4 inches (70 millimeters).
  - b. Apex (H) – 4 inches (100 millimeters).
  - c. Frustum height (h) – 2 inches (50 millimeters).
3. Draw in the reference lines from the apex (H) to the base (D). Check that the frustum diameter (d) is 1 3/8 inches (35 millimeters).
4. Develop the half circle representing half the bottom view.
5. Set the dividers at 1 3/8 inches (35 millimeters) - the radius of the base of the frustum (D). Divide the half circle into 6 equal sectors.
6. Label the marks 1 to 12 as indicated.
7. Project each of the sectors up to the base line at 90 degrees. Project these lines to the apex.
8. Develop the stretch out pattern of the frustum. Place the compass point on the apex. Set the radius to A and swing an arc as indicated. Repeat with the radius set to B.
9. Draw a line from the apex to the bottom circumference, away from the base of the frustum. The intersection point will be the start for marking out the base circumference into 12 sectors.



**Figure 8-18 — Radial-line development.**



10. The frustum circumference is  $D = 3.14 \times 2 \frac{3}{4}$  inches =  $8 \frac{43}{64}$  inches (220 millimeters). Mark the base circumference into 12 equal sectors. Calculate the length of each sector:

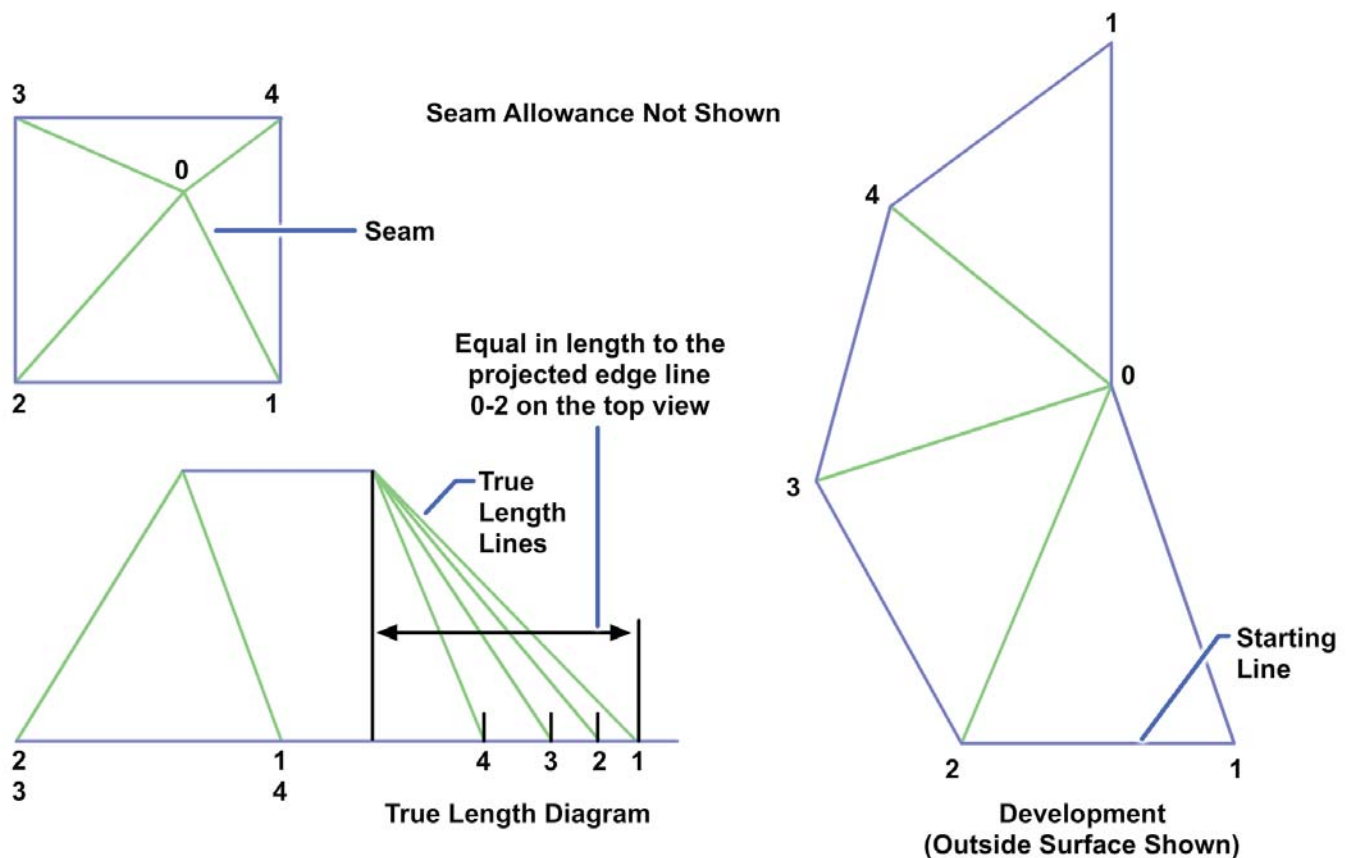
$$= 8 \frac{43}{64} \text{ inches (220 millimeters)} / 12 = 0.72 \text{ inches (18.3 millimeters)}$$

11. Draw a reference line and mark out  $23/32$  inch (18.3 millimeters). Set the dividers to this distance. Mark off the 12 divisions along the circumference.

12. Project each of these to the apex to form the radial lines. The radial lines will be used in the forming process. The shape shaded in blue is the radial-line stretch out pattern for the right cone frustum.

## Oblique Pyramid

The oblique pyramid in *Figure 8-19* has all its lateral edges of unequal length. The true length of each of these edges must first be found as shown in the true-length diagram. The development may now be constructed as follows:



**Figure 8-19 — Development of an oblique pyramid by triangulation.**

1. Lay out base line 1-2 in the development view equal in length to base line 1-2 found in the top view.
2. With point 1 as center and a radius equal in length to line 0-1 in the true diagram, swing an arc.
3. With point 2 as center and a radius equal in length to line 0-2 in the true-length diagram, swing an arc intersecting the first arc at 0.

4. With point 0 as center and a radius equal in length to line 0-3 in the true-length diagram, swing an arc.
5. With point 2 as center and radius equal in length to base line 2-3 found in the top view, swing an arc intersecting the first arc at point 3.
6. Locate points 4 and 1 in a similar manner, and join those points, as shown, with straight lines.

The base and seam lines have been omitted on the development drawing.

### Truncated Pyramid

The truncated pyramid in *Figure 8-20* has all its lateral edges of unequal length. The true length of each of these edges must first be found. The procedure for developing a truncated pyramid is given below. Check each step of the procedure against the development shown in *Figure 8-20*.

1. First draw the orthographic views of the truncated pyramid.
2. Identify the base diameter. Here the base diameter is 12 inches.
3. Identify and mark the height of the apex. Here the height is 12 inches.
4. Identify and mark the height of the truncated pyramid. Here the height is 8 inches.
5. Determine the angle of the top of the truncated pyramid and use a setsquare. Here the angle is 45 degrees.

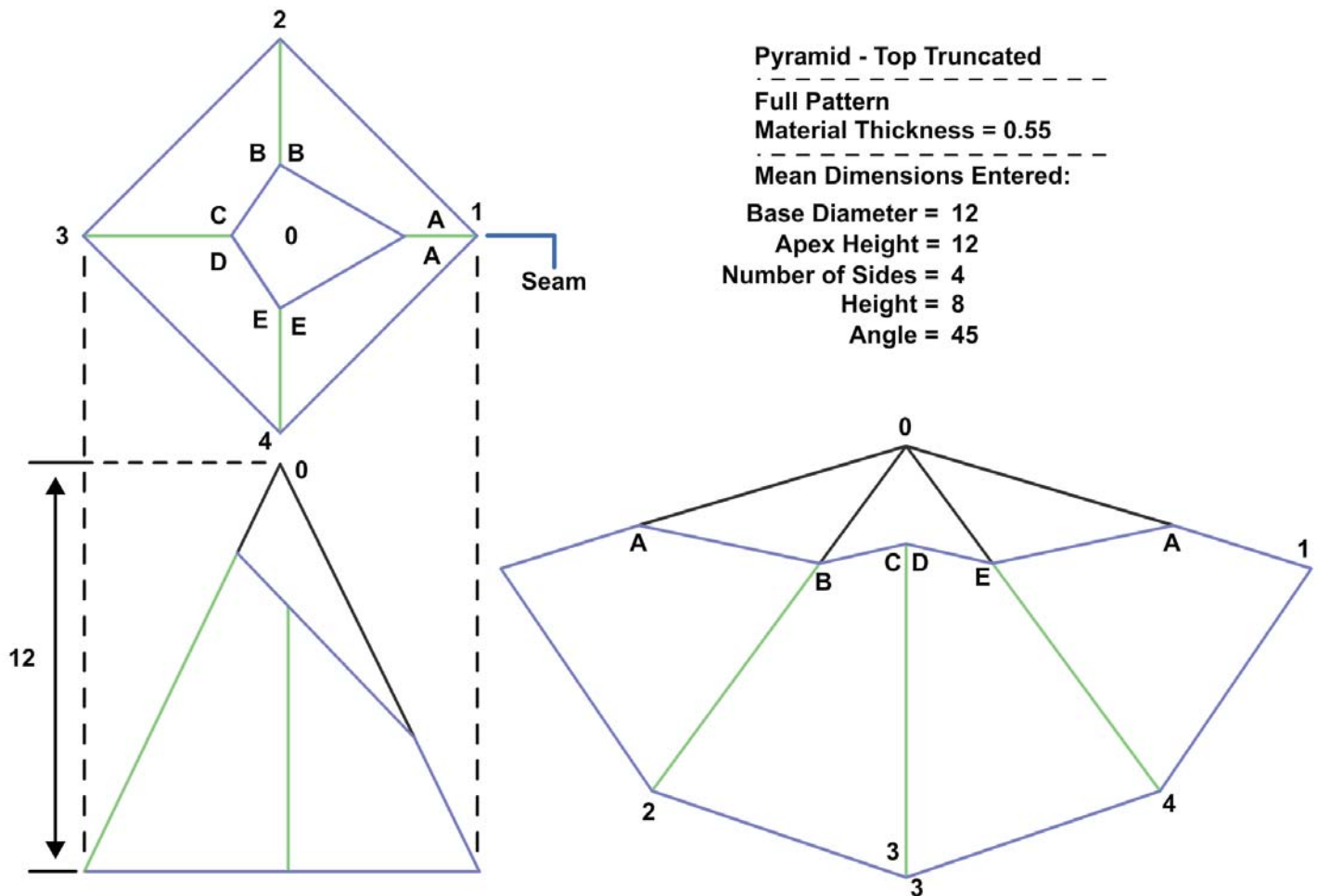


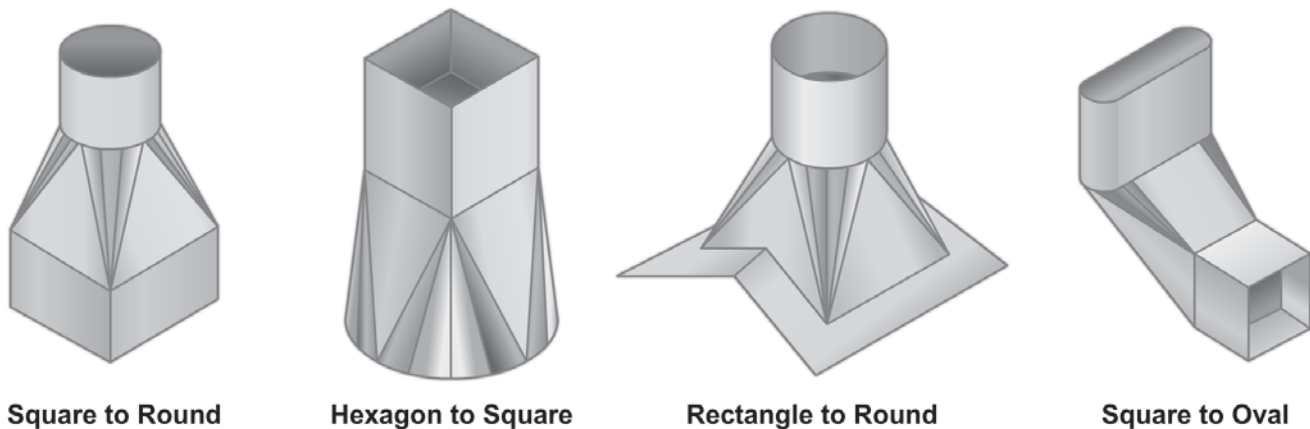
Figure 8-20 — Development of a truncated pyramid.

6. Mark off the radius on both sides of the reference line to construct the sides of the truncated pyramid.
7. The intersecting points establish the true length of all segments.
8. Now develop the stretch out pattern. Transfer the length of the lines on the side view to the corresponding lines on the stretch out view.
9. The final shape is the stretch out pattern of the cylindrical shape and can be cut to shape to use as a template.

## Triangular Development

Triangulation is slower and more difficult than parallel-line or radial-line development, but it is more practical for many types of figures. Additionally, it is the only method by which the development of warped surfaces may be estimated. In development by triangulation, the piece is divided into a series of triangles, as in radial-line development. However, there is no one single apex for the triangles. The problem becomes one of finding the true lengths of the varying oblique lines. Drawing a true-length diagram solves the problem.

An example of a layout using triangulation is the development of a transition piece (*Figure 8-21*). Transition pieces are usually made to connect two different shapes of pipes, such as square to round, rectangular to round, and hexagonal to round. Transition pieces can be used to form parallel and oblique joints where the piping may not be perpendicular to the pipe axis. These transition pieces will usually fit the definition of a non-developable surface that must be developed by approximation.



**Figure 8-21 — Transition pieces.**

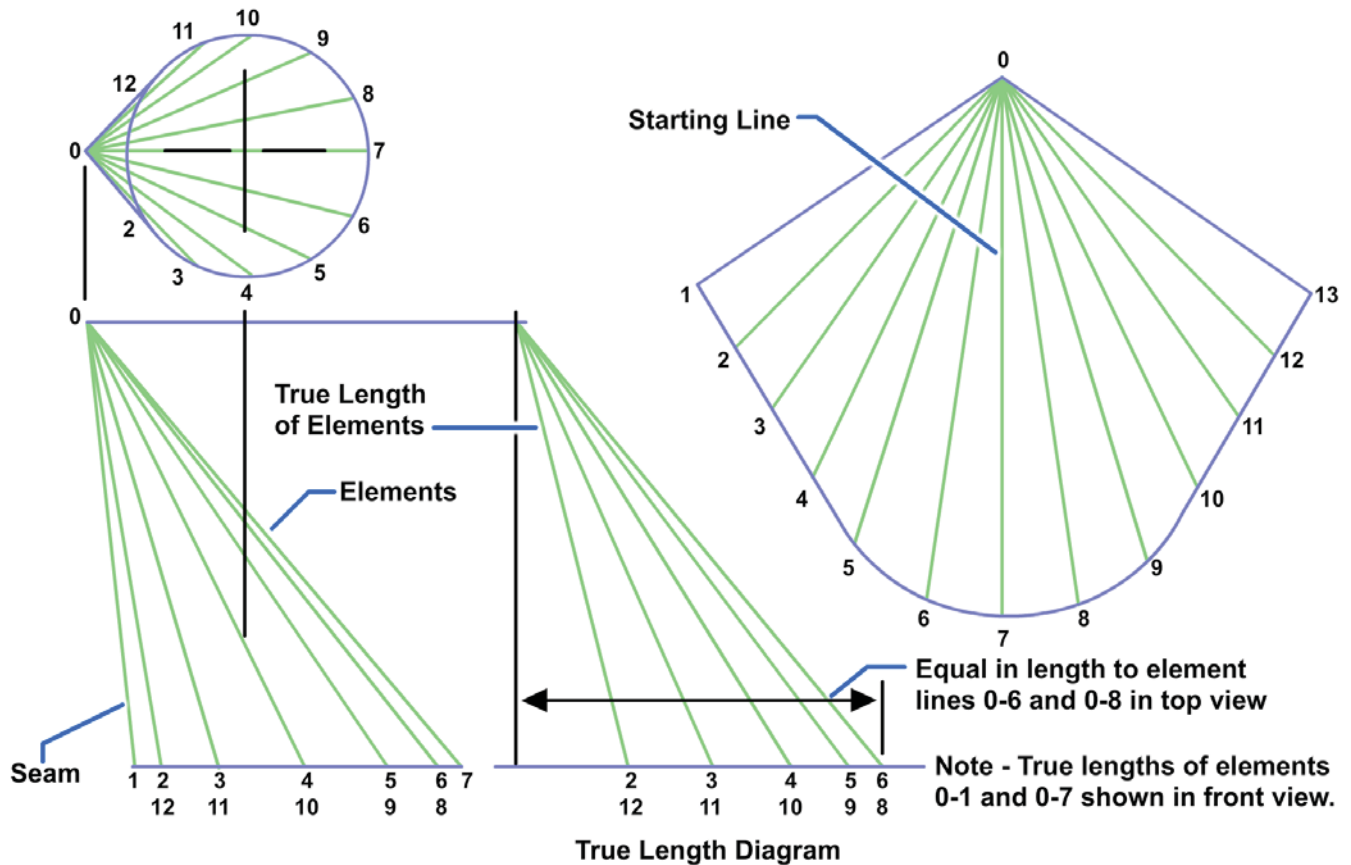
## Oblique Cone

An oblique cone is generally developed by the triangulation method.

The base of the cone is divided into an equal number of divisions. The elements 0-1, 0-2, and so on are drawn in the top view, projected down, and drawn in the front view. The true lengths of the elements are not shown in either the top or front view, but would be equal in length to the hypotenuse of a right triangle, having one leg equal in length to the projected element in the top view and the other leg equal to the height of the projected element in the front view. When it is necessary to find the true length of a number of edges, or elements, then a true-length diagram can be drawn adjacent to the front view, preventing the front view from being cluttered with lines.

Since the development of the oblique cone (*Figure 8-22*) will be symmetrical, the starting line will be element 0-13. The development is constructed as follows:

1. With 0 as center and the radius equal to the true length of element 0-12, draw an arc.
2. With 13 as center and the radius equal to distance 12-13 in the top view, draw a second arc intersecting the first point at 12. Draw element 0-12 on the development.
3. With 0 as center and the radius equal to the true length of element 0-11, draw an arc. With 11 as center and the radius equal to distance 11-12 in the top view, draw a second arc intersecting the first point at 11. Draw element 0-11 on the development.
4. Repeat these steps with the remaining elements until all element lines are located on the development view.

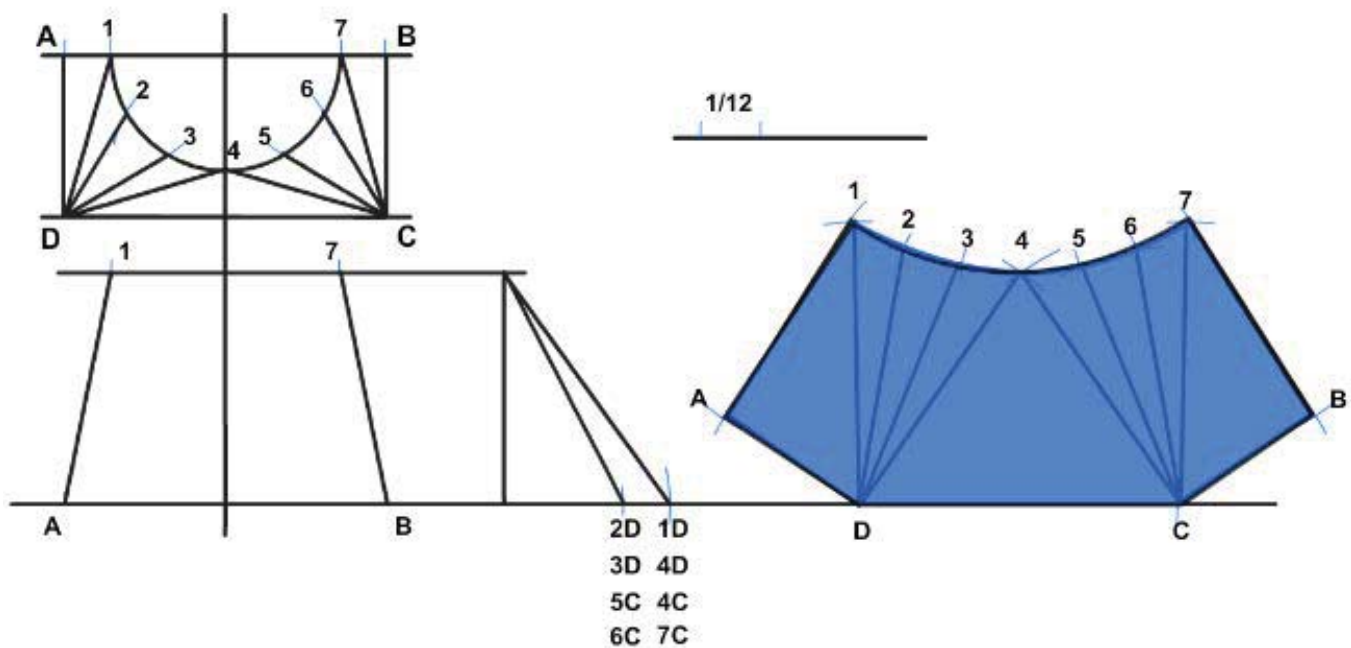


**Figure 8-22 — Development of an oblique cone.**

### Square-to-Round

The steps in the triangulation of a warped transition piece joining a large, square duct and a small, round duct are shown in *Figure 8-23*. The steps are as follows:

1. First establish the reference lines.
2. Develop the top view. With a set square, mark out the measurements for half the base, and label each corner (from the top left-hand corner, moving clockwise) A to D.
3. From the center of the half base, draw a semicircle with radius 1 inch (25 millimeter). Check that the diameter (D) is 2 inches (50 millimeters).



**Figure 8-23 — Triangular development of a transition piece.**

4. Divide the half circle into six equal spaces by placing the compass point on the three points where the semicircle intersects the reference lines and swinging small arcs ( $R = 1$  inch (25 millimeter)) to intersect the circle. Number the points 1 to 7 as shown.
5. Using a set square, draw lines from point D on the base of the shape to points 1 through to 4 on the half circle. Next, draw lines from C on the base of the shape to points 4 through to 7, which completes (half) the top view.
6. Draw the side view. First, draw a reference line. Remember, the vertical height is 50 millimeters, and the diameter of the top is 50 millimeters.
7. The base is  $2 \frac{3}{4}$  inches (70 millimeters) square. Draw lines from the base to the top. Label the base points A and B. Label the top points 1 and 7.
8. Now develop the stretch out pattern for the square-to-round. First establish a reference line (extending to the right from point B on the side view) for the base of the stretch out pattern. Draw the vertical height of the square-to-round somewhere to the right of the side view, perpendicular to the base line.
  - a. Now place the compass point on D in the top view. Set the radius to point 2 on the half circle. Place the compass point at the intersection of the base line and the vertical height line and swing an arc to mark the base line. Label this point 2D. Note this point is the shortest distance from point D to the top of the half circle, the same length as 3D, 5C, and 6C.
  - b. Now place the compass at D and set the radius to point 1 on the half circle. Transfer the compass to the intersection of the base line and the vertical height line and swing an arc to mark the base line. Label the point 1D. Note this point is the longer distance from point D to the top of the half diameter, the same length as 4D, 4C, and 7C.
  - c. Now draw a line from the top of the vertical height line to point 2D, and then from the top to point 1D. This diagram is called the true-length diagram.



9. Mark a point on the base line to the right of point 1D.
10. Set the compass at the distance between D and C on the top view (the true length), then transfer the distance D to C to the base line. Label the points D and C. Reset the compass to the length of the line 4D. Placing one point on D, draw an arc midway between D and C. Shift the compass to C, draw an arc to bisect the previous one. Label this point 4.
11. Mark out a new short reference line for one-twelfth of the circumference of the top of the square-to-round shape. Calculate the circumference of the top of the shape, and then divide it by 12.
 
$$C = \pi D$$

$$C = 3.14 \times 2 \text{ inches (50 millimeters)}$$

$$= 6 \frac{13}{64} \text{ inches (157 millimeters)}$$
 One-twelfth of the circle
 
$$= 6 \frac{13}{64} \text{ inches (157 millimeters)} \div 12$$

$$= \frac{1}{2} \text{ inch (13 millimeters)}$$
12. Measure and mark out 1/2 inch (13 millimeters) on the reference line. Set the compass at 1/2 inch (13 millimeters) (one-twelfth circumference).
  - a. Place the compass on point 4, and swing arcs to mark to the right and to the left. Set the compass at the true length of reference line 2D. Place the compass on point D, and swing an arc to intersect the arc on the left. Label this point 3. Place the compass on C, and swing an arc to intersect the arc on the right. Label this point 5.
  - b. Reset the compass at 1/2 inch (13 millimeters), using the measure on the reference line. Place the compass on point 5 and swing an arc to the right hand side. Swing an arc to the left of point 3.
  - c. Reset the compass at the length of the reference line 2D. Place the compass on point D, make a mark intersecting the arc, and label this point 2. Place the compass on C, make a mark intersecting the arc, and label this point 6.
  - d. Repeat the process, swinging an arc R13 to the left of 2 and right of 6. This time, however, reset the compass to the length of reference line 1D. Place the compass point on D, make a mark intersecting the arc, and label this point 1. Place the compass on C and make a mark intersecting the arc. Label this point 7.
13. Develop the half square base from point D to point A.
  - a. Using the side view diagram, set the compass at the distance between B and 7. Place the compass at point 1 on the stretch out pattern, and draw an arc to the lower left. Repeat the process from point 7 to the lower right.
  - b. Reset the compass to the distance between B and C on the top view diagram. Place the compass on D and make a mark intersecting the arc. Label this point A. Place the compass on C, make a mark intersecting the arc, and label this point B.
  - c. Using a set square or ruler, draw lines joining 1 and A; A and D; 7 and B; and B and C. Draw lines from D to 1, 2, 3, and 4. Draw lines from C to 4, 5, 6, and 7.
14. Use a flexible ruler, or freehand to join points 1 to 7.

This completes the stretch out half pattern for a square-to-round shape, using the triangulation method. This development does not show a seam allowance.

## Rectangular-to-Round

The transition piece shown in *Figure 8-24* is constructed in the same manner as the square-to-round except that all the elements are of different lengths. To avoid confusion, four true-length diagrams are drawn and the true-length lines are clearly labeled.

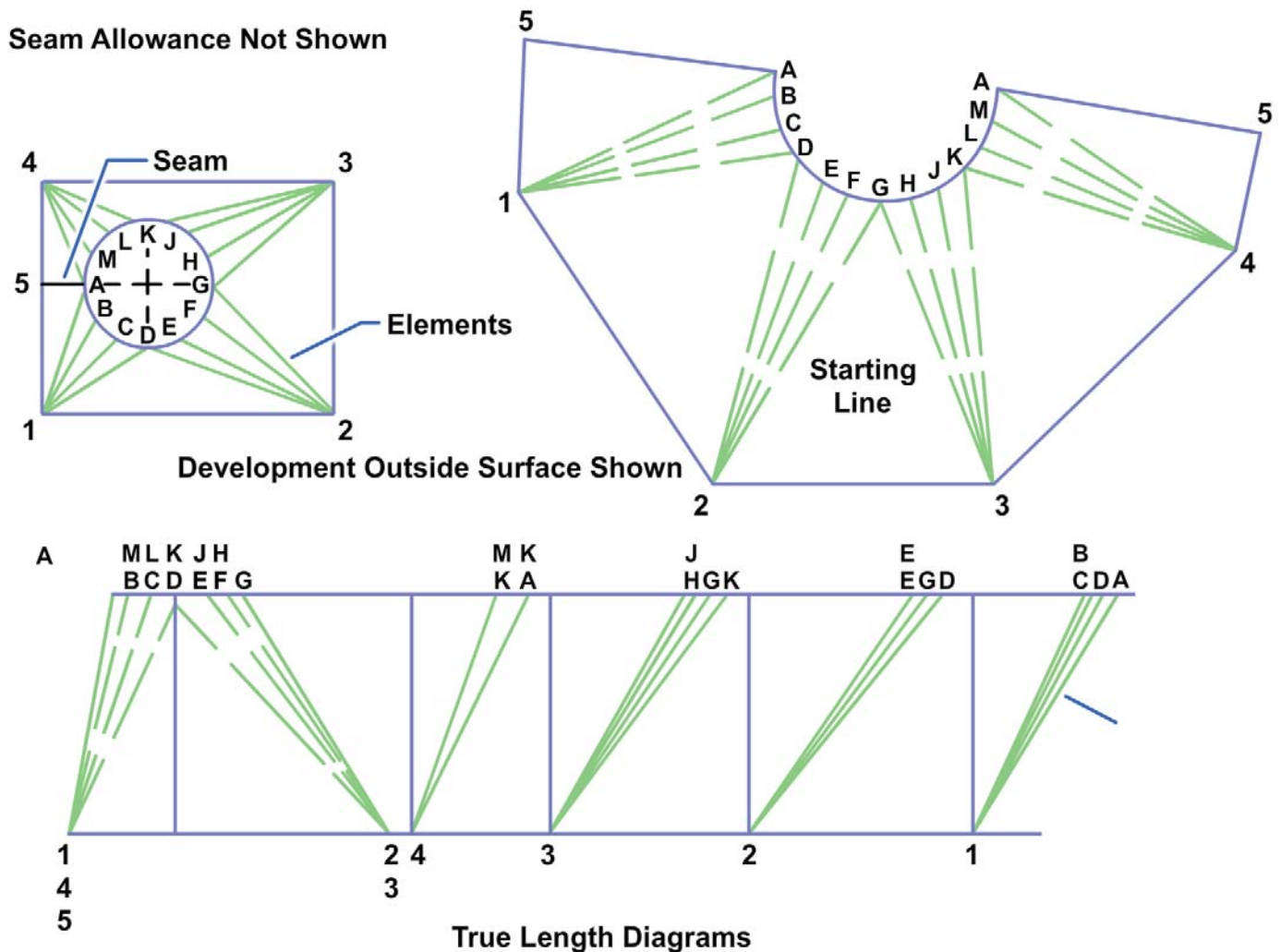


Figure 8-24 — Development of an offset transition piece—rectangular to round.

## Hexagon-to-Round

The transition piece shown in *Figure 8-25* is constructed in the same manner as the square-to-round and the rectangular-to-round transition pieces, as all of the elements are, once again, different lengths.

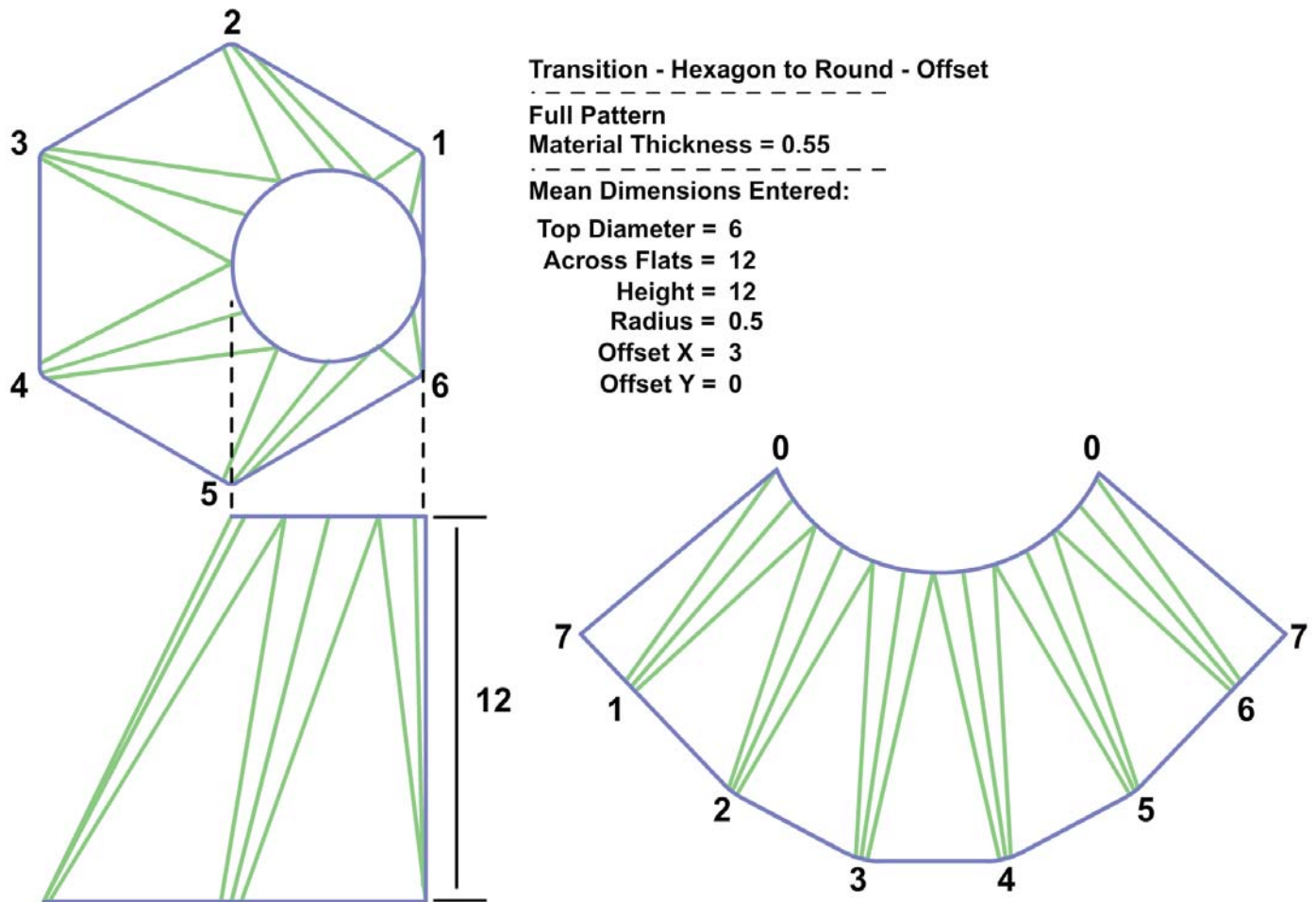


Figure 8-25 — Development of a transition piece—hexagon to round.

## End of Chapter 8

### Developments and Intersections

#### Review Questions

- 8-1. For which of the following reasons should the sheet metal development drawings allow additional material?
- A. Compression during shaping
  - B. Damage to the material
  - C. Joining of edges
  - D. Miscalculations
- 8-2. When drawing a lap seam, the allowance must be how many times the diameter of the rivet being used?
- A. 1
  - B. 3
  - C. 5
  - D. 7
- 8-3. If the finished part is not shown with the development, what item should be included?
- A. A scale model
  - B. Drawing instructions
  - C. Color code list
  - D. Marking instructions
- 8-4. Which of the following terms describes the amount of material consumed in making a bend?
- A. Base measurement
  - B. Bend allowance
  - C. Bend tangent line
  - D. Setback
- 8-5. The three procedures commonly used in developing patterns are parallel-line, radial-line, and what other type of development?
- A. Circular
  - B. Perspective
  - C. Rectangular
  - D. Triangular
- 8-6. Which of the following statements defines parallel-line development?
- A. The development of an object that has surfaces on a flat plane of projection
  - B. The development of an object that has surfaces on a slanting plane of projection
  - C. The first series of prints used in construction and manufacturing
  - D. The perspective print of the development of parallel roadways

- 8-7. The parallel-line development is based upon which of the following principles?
- A. A line parallel to another line is an equal distance from that line at all points
  - B. A line perpendicular to another line will intersect at only one point
  - C. The lines radiate from the apex of a cone
  - D. When finished, the lines form a three-dimensional drawing
- 8-8. What type of development is used when an object has the same cross-sectional shape throughout the length?
- A. Orthographic-perspective
  - B. Parallel-line
  - C. Radial-line
  - D. Triangular
- 8-9. Which of the following shapes is an exception to the normal practice of placing seams on the shortest side in sheet metal development?
- A. Cone
  - B. Cylinder
  - C. Elbow
  - D. Pyramid
- 8-10. In what type of development do the slanting lines of pyramids and cones not always appear in the true lengths?
- A. Orthographic-perspective
  - B. Parallel-line
  - C. Radial-line
  - D. Triangular
- 8-11. Concerning radial-line developments, which of the following statements is true?
- A. A line parallel to another line is an equal distance from that line at all points
  - B. A line perpendicular to another line will intersect at only one point
  - C. The lines radiate from the apex of a cone
  - D. When finished, the lines form a three-dimensional drawing
- 8-12. In a radial-line development, the reference lines are transferred from what view to the development?
- A. Front
  - B. Rear
  - C. Side
  - D. Top



- 8-13. In a radial-line development of an oblique pyramid, what measurement must be found first?
- A. Apex height
  - B. Base
  - C. Frustum height
  - D. Lateral edges
- 8-14. What type of development is slow and difficult to draw?
- A. Orthographic-perspective
  - B. Parallel-line
  - C. Radial-line
  - D. Triangular
- 8-15. When using triangular development, to find the true length of the varying oblique lines, what type of diagram is drawn?
- A. Block
  - B. True length
  - C. Reference
  - D. Architect scale
- 8-16. Which of the following items is an example of using triangular development?
- A. Rectangular box
  - B. Straight connections
  - C. Transition pieces
  - D. Truncated pyramid
- 8-17. In drawing an oblique cone, the elements are first drawn in which of the following views?
- A. Front
  - B. Rear
  - C. Side
  - D. Top
- 8-18. Which of the following is the first step in developing a square-to-round transition piece?
- A. Establish reference lines
  - B. Create a true-length diagram
  - C. Develop the top view
  - D. Draw a semicircle

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# INDEX

- Addendum, 4-7
- Addendum circle, 4-8
- Adjustable triangles, 2-6
- Aligned section, 3-18
- Aircraft electrical prints, 6-9
  - wire and cable identification, 6-10
- Aircraft electronics prints, 6-19
  - electromechanical drawings, 6-21
  - wiring diagrams, 6-20
- Aircraft wire and cable identification, 6-10
- Alternate position of isometric axis, 3-10
- Angles in isometric projection, 3-8
- Angles, 7-3
- Application block, 1-6
- Architectural and structural steel drawings, 7-1
  - construction plans, 7-18
  - drawings of steel structures, 7-17
  - structural shapes and members, 7-1
  - welded and riveted steel structures, 7-9
- Auxiliary view, 3-13
- Axis, 4-6
- Base measurement, 8-5
- Basic logic diagrams, 6-24
- Beam compass, 2-10
- Bearing pile, 7-2
- Bend allowance terms, 8-5
  - base measurement, 8-5
  - bend allowance, 8-5
  - bend tangent line, 8-5
  - closed angle, 8-6
  - flange, 8-5
  - flat, 8-5
  - K number, 8-6
  - leg, 8-5
  - mold line, 8-5
  - open angle, 8-6
  - radius, 8-5
  - setback, 8-5
- Bend allowance, 8-5
- Bends, 8-4
  - bend allowance formula, 8-6
  - bend allowance terms, 8-5
- Bend tangent line, 8-5
- Bill of material, 1-5
- Block diagram, 6-1, 6-6, 6-12
- Blueprint numbering plan, 1-10
- Blueprint parts, 1-2

- application block, 1-6
- bill of material, 1-5
- drawing number, 1-3
- finish marks, 1-7
- information blocks, 1-2
- legends and symbols, 1-8
- notes and specifications, 1-7
- production, 1-1
- reference number, 1-3
- revision block, 1-3
- scale block, 1-4
- station number, 1-4
- title block, 1-2
- zone number, 1-4
- Blueprints, 1-1
  - filing and handling, 1-11
  - meaning of lines, 1-8
  - numbering plan, 1-10
  - parts, 1-2
  - production, 1-1
  - shipboard blueprints, 1-10
  - standards, 1-2
- Break lines, 2-16
- Broken-out section, 3-18
- Cable marking, 6-3
  - new tag system, 6-4
  - old tag system, 6-3
- Center lines, 2-13
- Channels, 7-3
- Chordal pitch, 4-8
- Circles in isometric projection, 3-9
- Circular pitch, 4-8
- Clearance, 4-8
- Closed angle, 8-6
- Columns, 7-4
- Common terms and symbols, 4-1
  - general terminology, 4-1
- Compasses, 2-8
- Computer-aided design/computer-aided manufacturing, 2-21
- Computer-aided drafting (CAD), 2-19
  - digitizer, 2-20
  - generating drawings, 2-20
  - plotter, 2-20
  - printer, 2-21
- Computer logic, 6-21
- Computer numerical control, 2-21
- Construction lines, 2-13
- Construction plans, 7-18
  - detail drawings, 7-25
  - general drawings, 7-20
  - specifications, 7-31

- Connections, piping, 5-4
- Connection diagram, 6-7
- Crest, 4-6
- Crossings, piping, 5-3
- C-shape, 7-3
- Datum lines, 2-17
- Dedendum, 4-8
- Depth, 4-7
- Detail drawings, 3-19, 7-25
  - detail views, 7-27
  - sectional views, 7-25
- Detail view, 7-27
- Detailed logic diagrams, 6-24
- Development, types of, 8-7
  - parallel-line development, 8-7
  - radial-line development, 8-11
  - triangular development, 8-14
- Developments and intersections, 8-1
  - bends, 8-4
  - seams, joints, and edges, 8-1
  - sheet-metal sizes, 8-5
  - types of development, 8-7
- Diagonal hatching in isometric projection, 3-10
- Diametral pitch, 4-7
- Digitizer, 2-20
- Dimension lines, 2-15
- Dimensioning, 7-13
- Dimetric projections, 3-10
- Dividers, 2-8
- Drafting tables with boards, 2-4
- Drawing aids, 2-4
  - adjustable triangles, 2-6
  - beam compass, 2-10
  - compasses, 2-8
  - dividers, 2-8
  - drafting tables with boards, 2-4
  - drop bow pen, 2-9
  - French curves, 2-7
  - instrument sets, 2-7
  - proportional dividers, 2-10
  - protractors, 2-6
  - triangles, 2-5
  - T-squares, 2-5
- Drawing instrument sets, 2-7
  - compasses, 2-8
  - dividers, 2-8
  - drop bow pen, 2-9
  - maintenance of compasses and dividers, 2-9
  - beam compass, 2-10
  - proportional dividers, 2-10
- Drawings of steel structures, 7-17