Chapter (6-B)

# Corrosion Control
# By
# Design Considerations

# INTRODUCTION

- A good design at the blackboard is no more costly than a bad design… a bad design is always more expensive than a good design in reality.
- Design has a critical role to play in the service life of components.
- The important point is that the designers must have an understanding and awareness of corrosion problems
- More attention is paid to the selection of corrosion resistant materials for a specific environment, and a minimal consideration is given to design, which leads to equipment failure.
- This has been a common observation in desalination plants in the Gulf region.
- We will highlight how corrosion could be prevented by adopting good design practices.

# SERVICE LIFE OF EQUIPMENT

Selection of a corrosion resistant material for the environment is a prerequisite to a good design.

Materials and design are complimentary to each other and neither of the two can be ignored.

The following factors influence the service life of equipment:

1) Environment and geographic location
2) Selection of materials
3) Maintenance
4) Corrosive environment and velocity of flow
5) Design
6) Features promoting corrosion:
   e.g. Bimetallic connections.

# CAUSES OF FAILURES IN DESIGN CONTEXT

- A good engineering design should provide
  1. a maintenance-free service,
  2. satisfy the end user, and
  3. provide a maximum return on capital in a shortest return period.

*However, there are several areas related to failure as show below.*

**1) Breakdown of protective system:** Many protective surface treatments, such as *coating and welding*, may not be very effective because of the presence of surface irregularities, voids, surface porosity, undercuts and general surface roughness.

The surface heterogeneities act as moisture traps and cause the damage.

**2) Poor fabrication**: Factors, such as *improper welding, excessive cold working and excess machining* lead to failure.

**3) Lack of accessibility.**

In complex systems, machinery, and components, there might be *inaccessible areas due to lack of design insight* where it may not be possible to carry out the corrosion protection measures.

Interiors of car doors are examples which are subjected to intensive localized corrosion.

**4) Structural heterogeneity in materials**.

Joining similar materials with structural differences, such as differences in *thermo-mechanical processing, grain size, number of impurity elements, grain boundary segregates*, may cause deviation from the performance expected.

**5) Operating conditions.**

Factors, such as *temperature, pressure and velocity* influence the service life if allowed to exceed the prescribed limits.

# Consideration of Corrosive Environment

- The metal or alloy must have a proven compatibility to the corrosive environment.

  - For instance, stainless steel (SS) 316 with 2% Mo is a better material for seawater service than SS 304 without molybdenum.

  - Brass, bronze and copper based alloys are highly desirable for salt water transportation. However, they are vulnerable for an environment containing ammonia frequently encountered in agriculture.

- A good design to prevent corrosion must be compatible with the corrosive environment.

# Specific Design Items

Design items which affect the rate of corrosion include the following:

1) Stresses acting on the materials in service.
2) Relative velocity of the medium and obstacles to flow.
3) Bimetallic contacts.
4) Crevices.
5) Riveted joints.
6) Spacing for maintenance.
7) Drainage and directional orientation of loop.
8) Joints to avoid entrapment.
9) Sharp corners.
10) Non-homogeneous surface.

## CONSIDERATION OF AREAS REQUIRING ATTENTION AT THE DESIGN STAGE

*<u>The following are the areas which require attention to minimize corrosion:</u>*

1. Bimetallic contacts
2. Faying surface
3. Crevices
4. Moisture traps
5. Water traps
6. Welds
7. Inaccessibility
8. Areas of condensation
9. Fluid movements
10. Metals in contact with moisture absorbent materials
11. Features which reduce the paint thickness
12. Oil, grease, rust patches
13. Joints: threaded, riveted, screwed
14. Closed sections and entrapment areas
15. Mechanical factors
16. Corrosion awareness

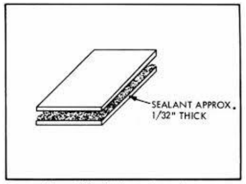


FIGURE 3.23.—Faying surface sealing.

Effects of *<u>some factors stated above</u>* on design are briefly described.

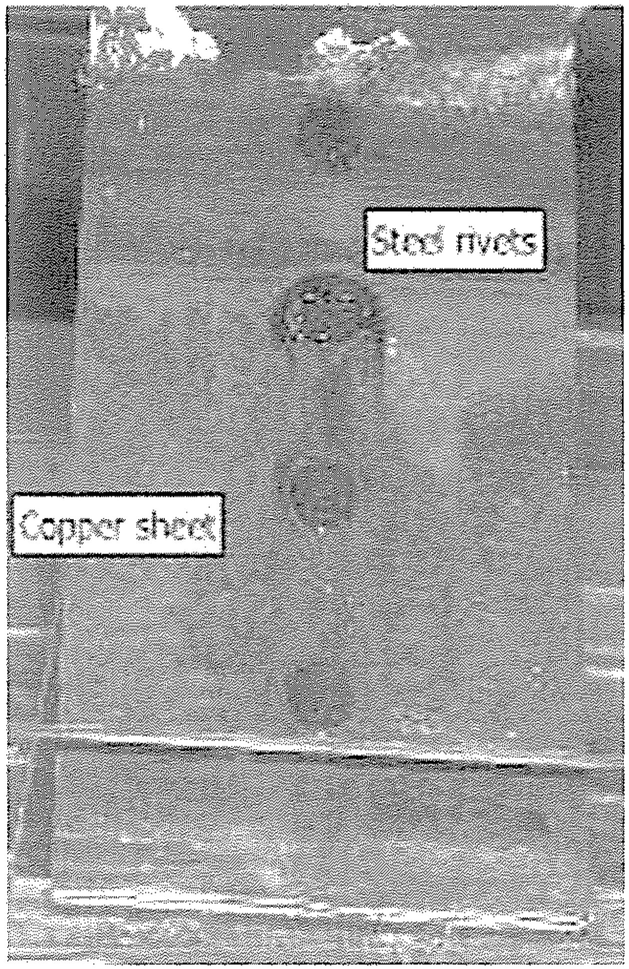



Figure 8.5a Steel rivets in copper sheets

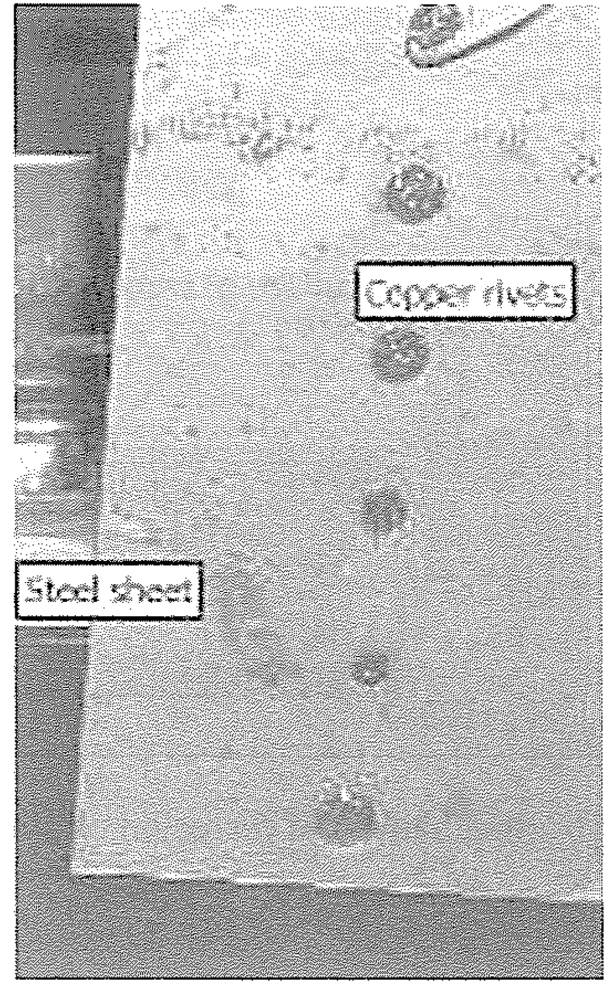



Figure 8.5b Copper rivets in steel sheets

# Joints

## Riveted

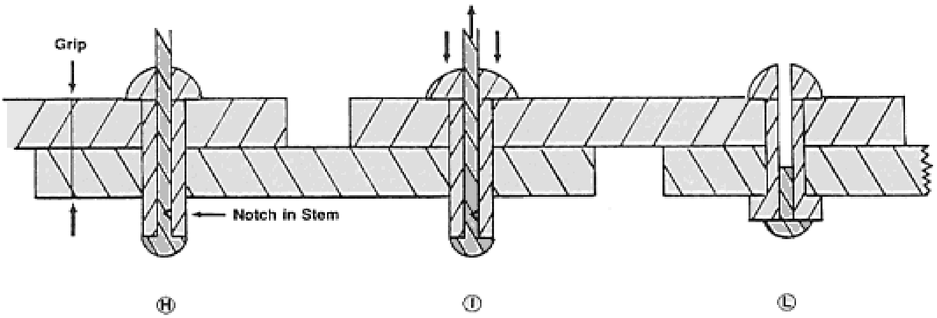
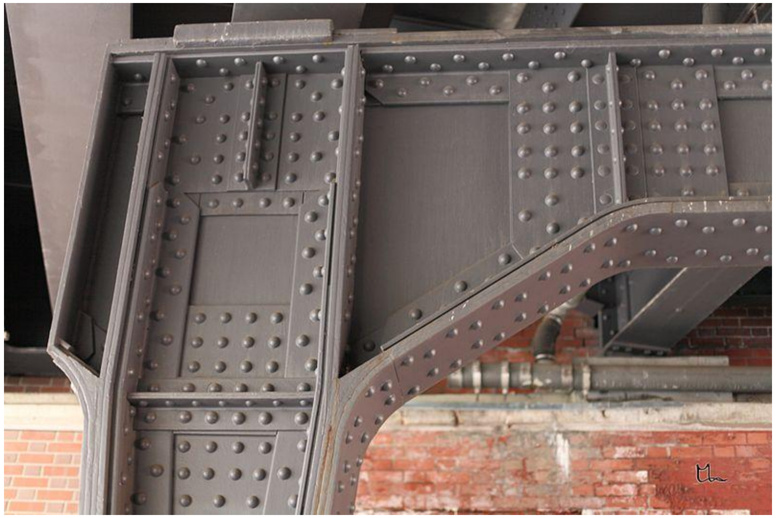



Fig. ③
AVDEL-AVEX Blind Rivet



## Threaded

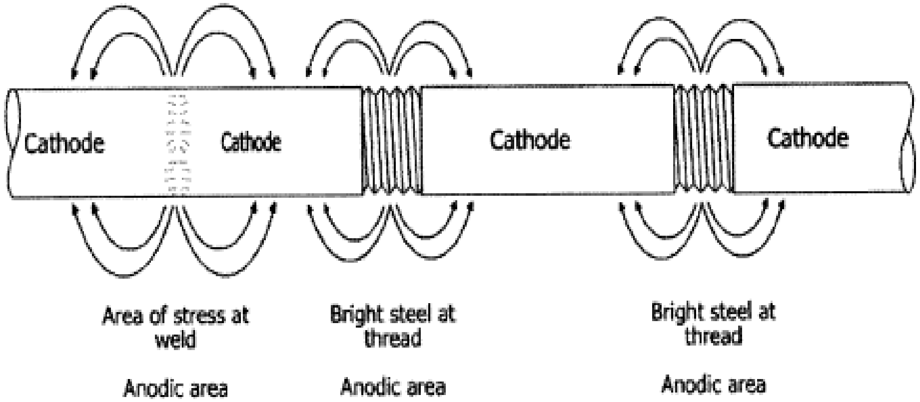
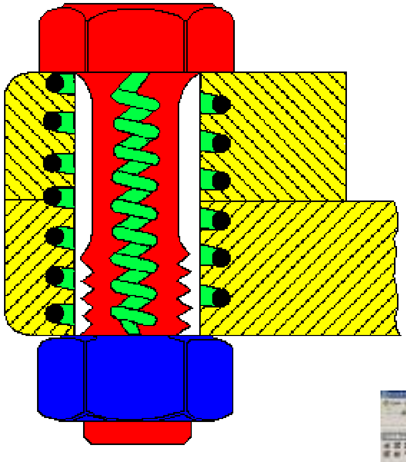
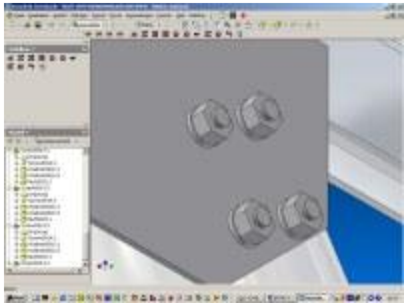



Figure 5.7 Stress cell. Corrosion caused by areas of stress and areas of bright steel on an underground pipeline



## Bolted



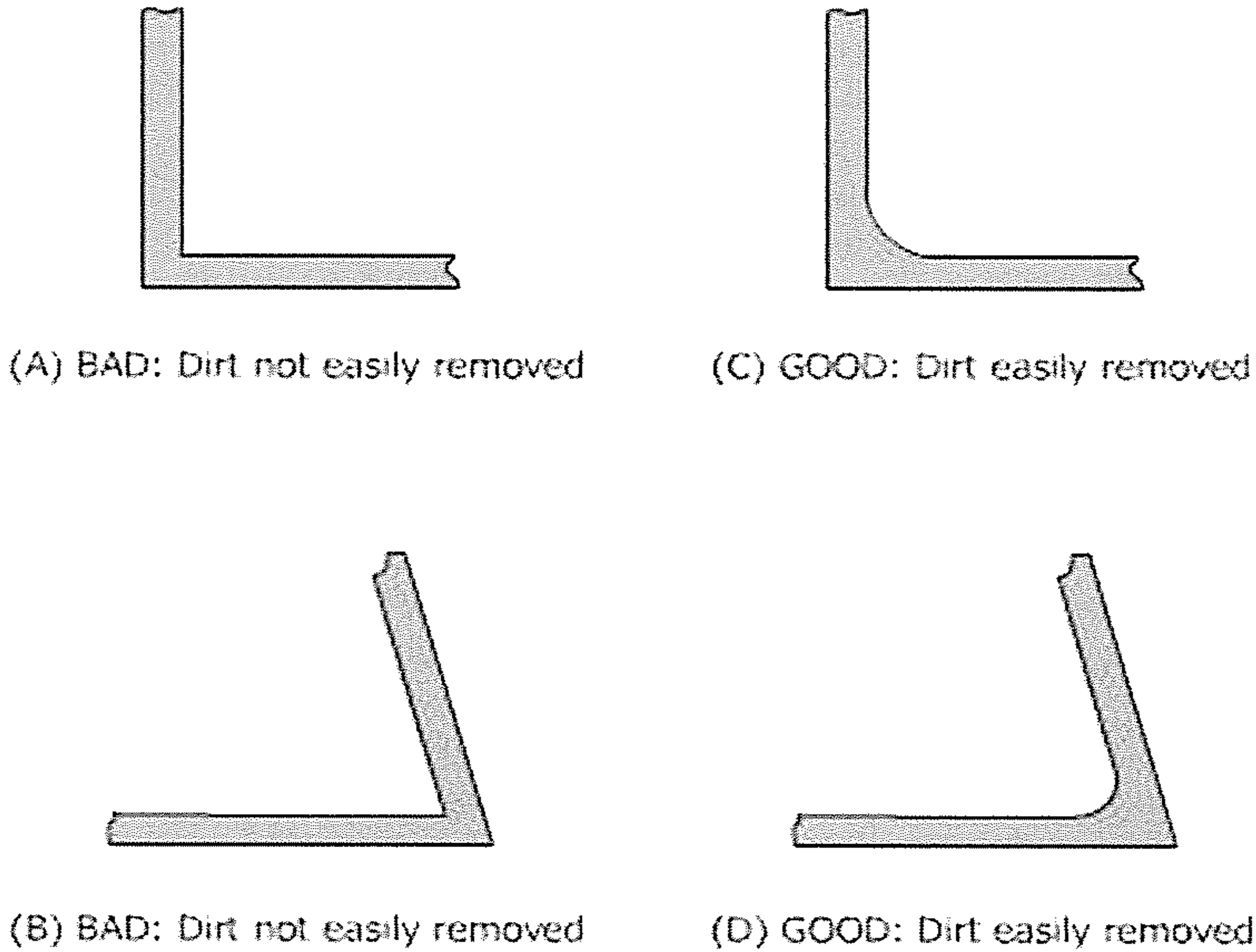



**Figure 8.7** Good and bad designs for removal of dirt

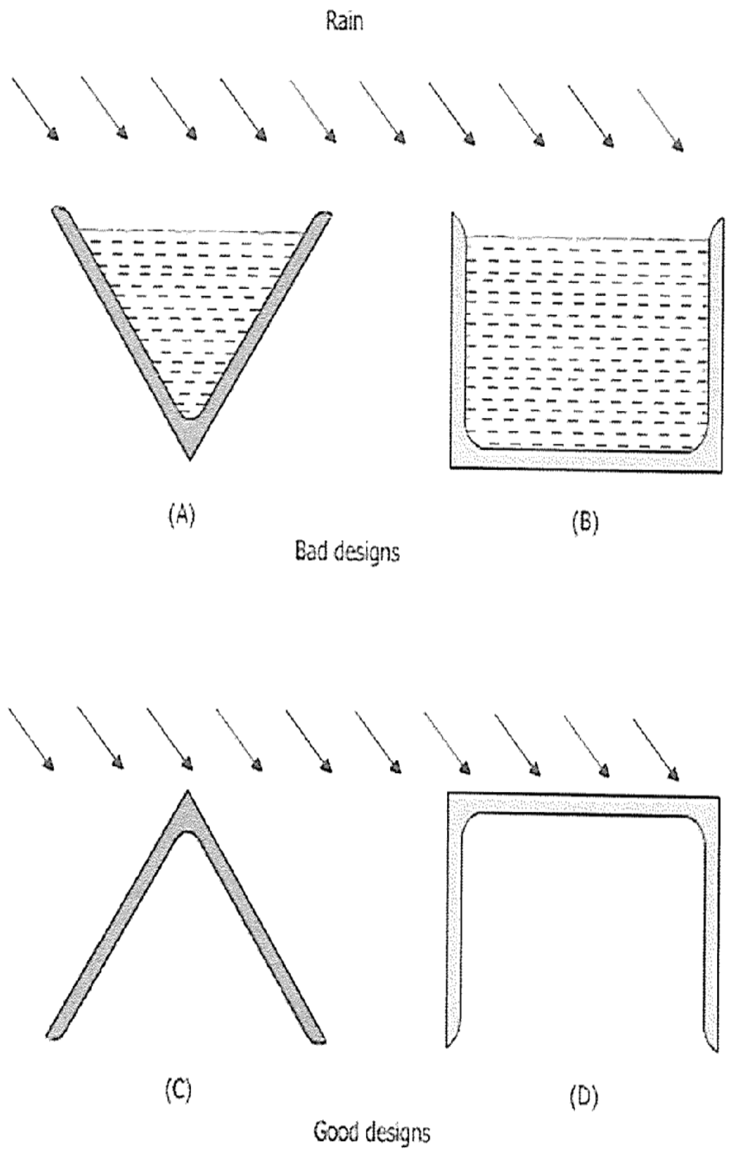



Figure 8.8 Preventing rainwater from lodging on steel structures

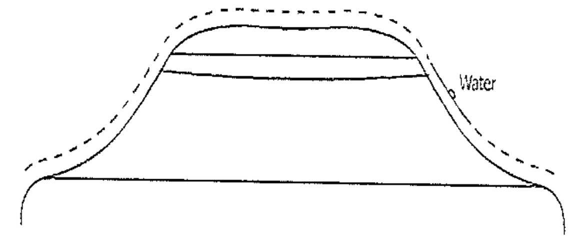



Figure 8.9a A structural member of automobile

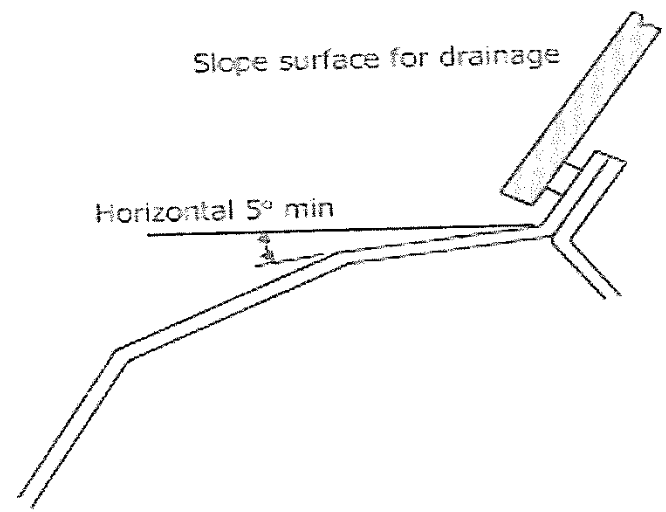



Figure 8.9b Proper design of panels

## To avoid retention of water (moisture) layer on channel surface in case of bi-metallic contact

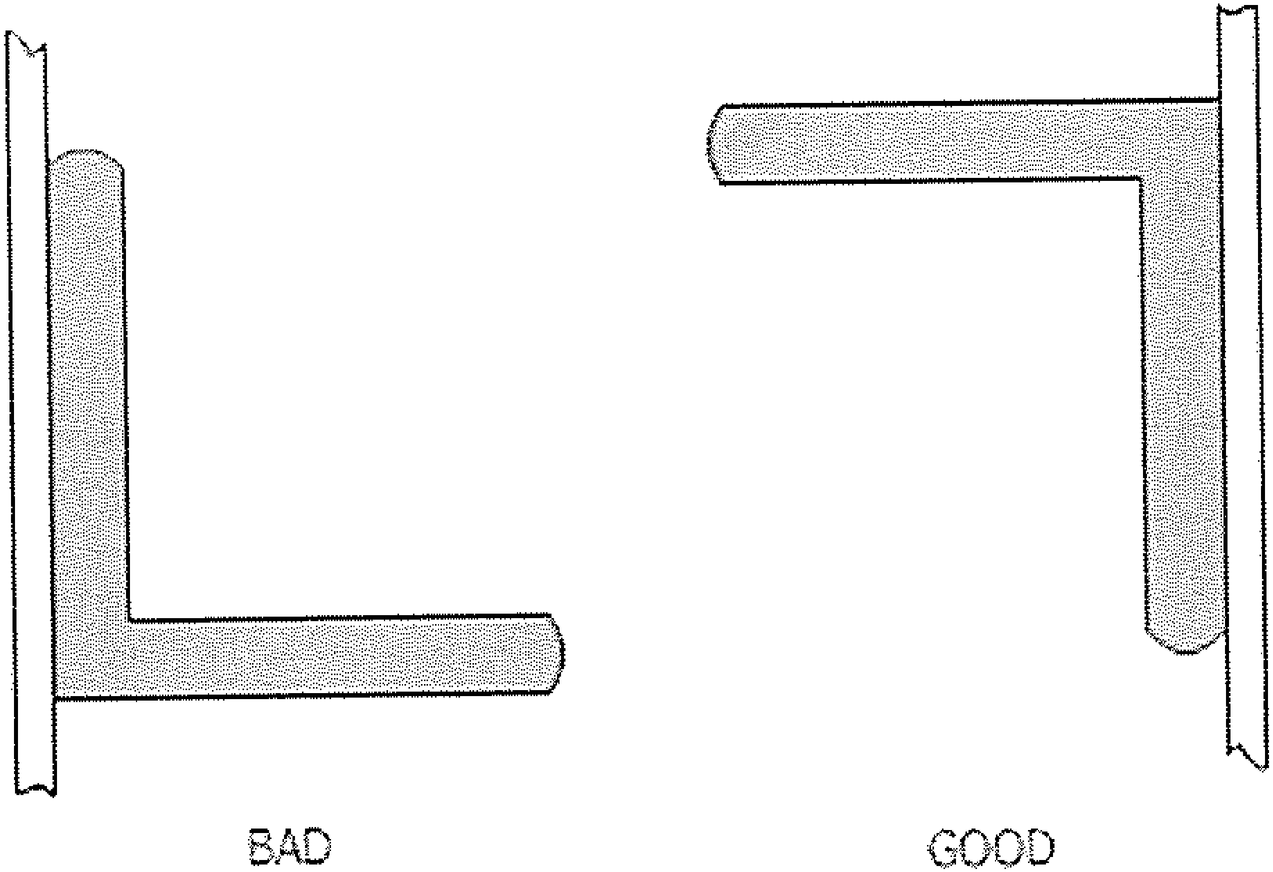



**Figure 8.10** Good and bad design of channels

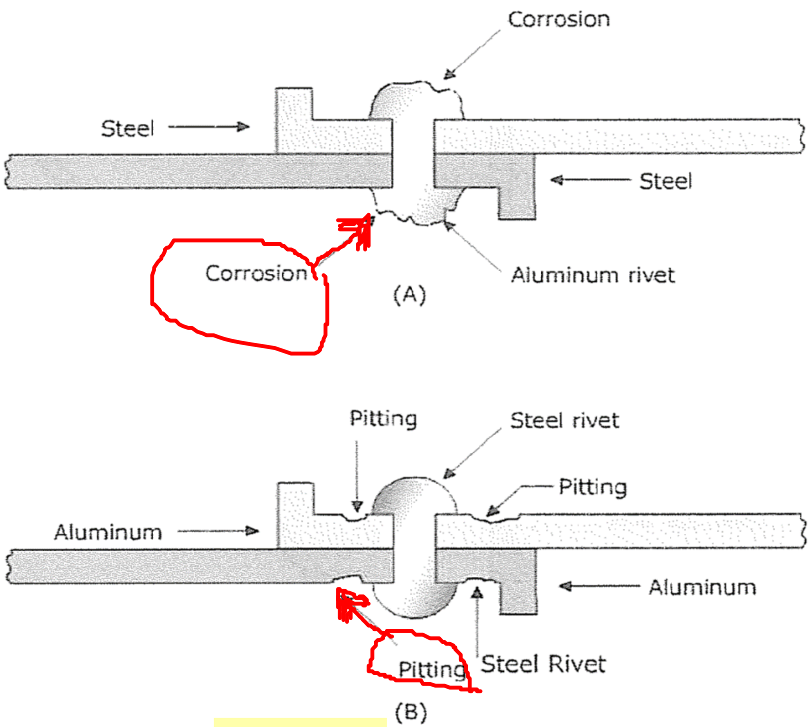



**Figure 8.16** A bad design approach (no insulation)

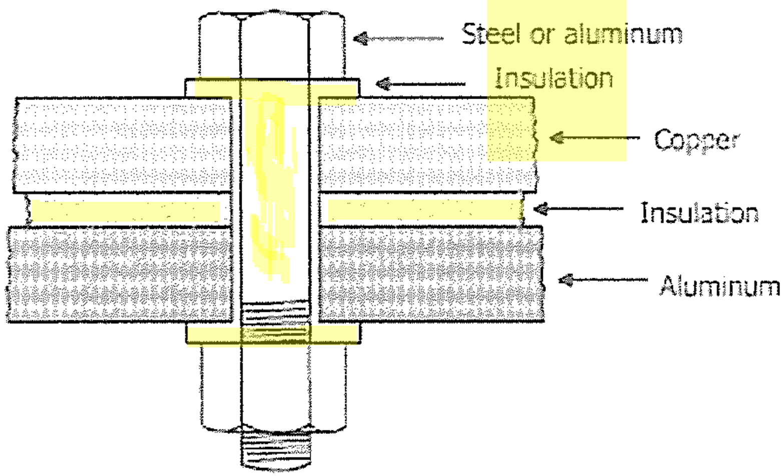
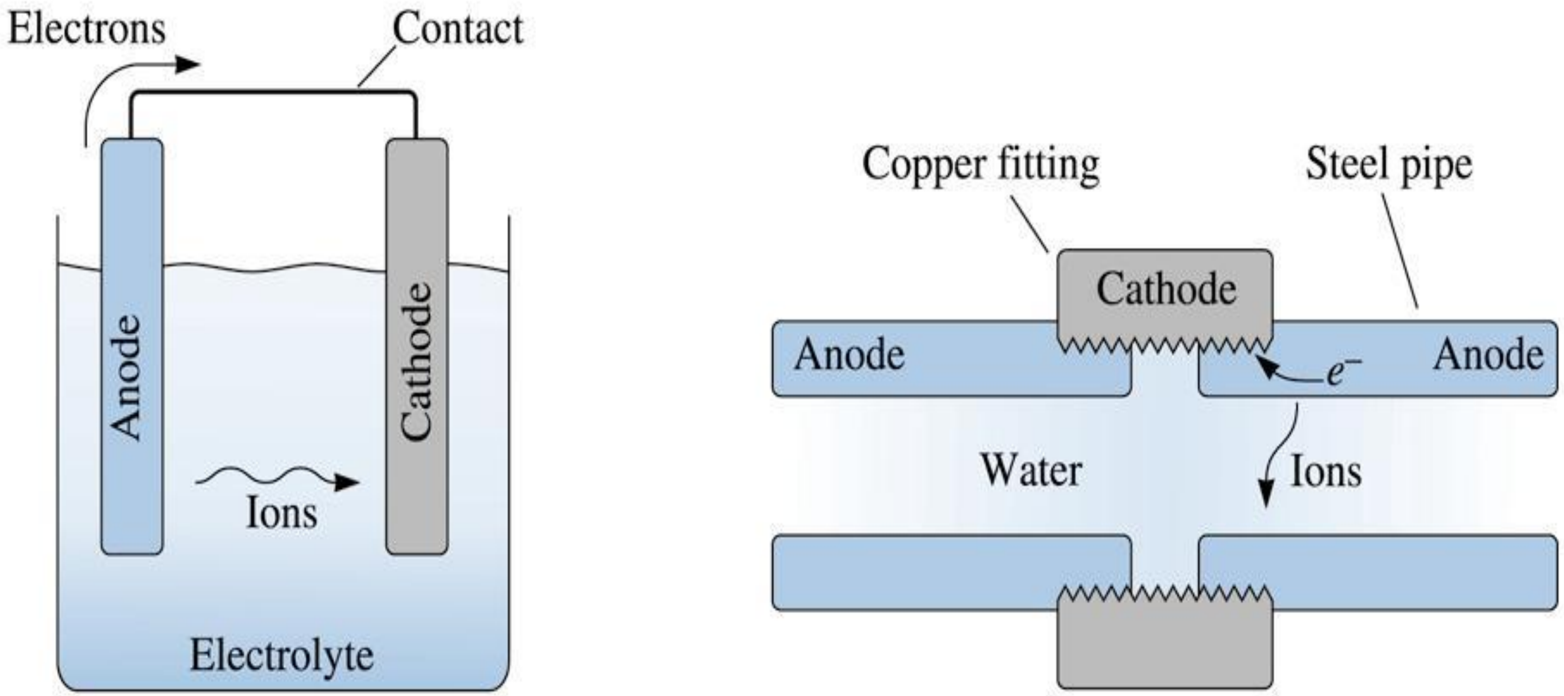



**Figure 8.17** Illustration of a good bolted joint




(a) (b)



**Figure** The components in an electrochemical cell:
(a) simple electrochemical cell , and
(b) a corrosion cell between a steel water pipe and a copper fitting.

# Insulated Joints

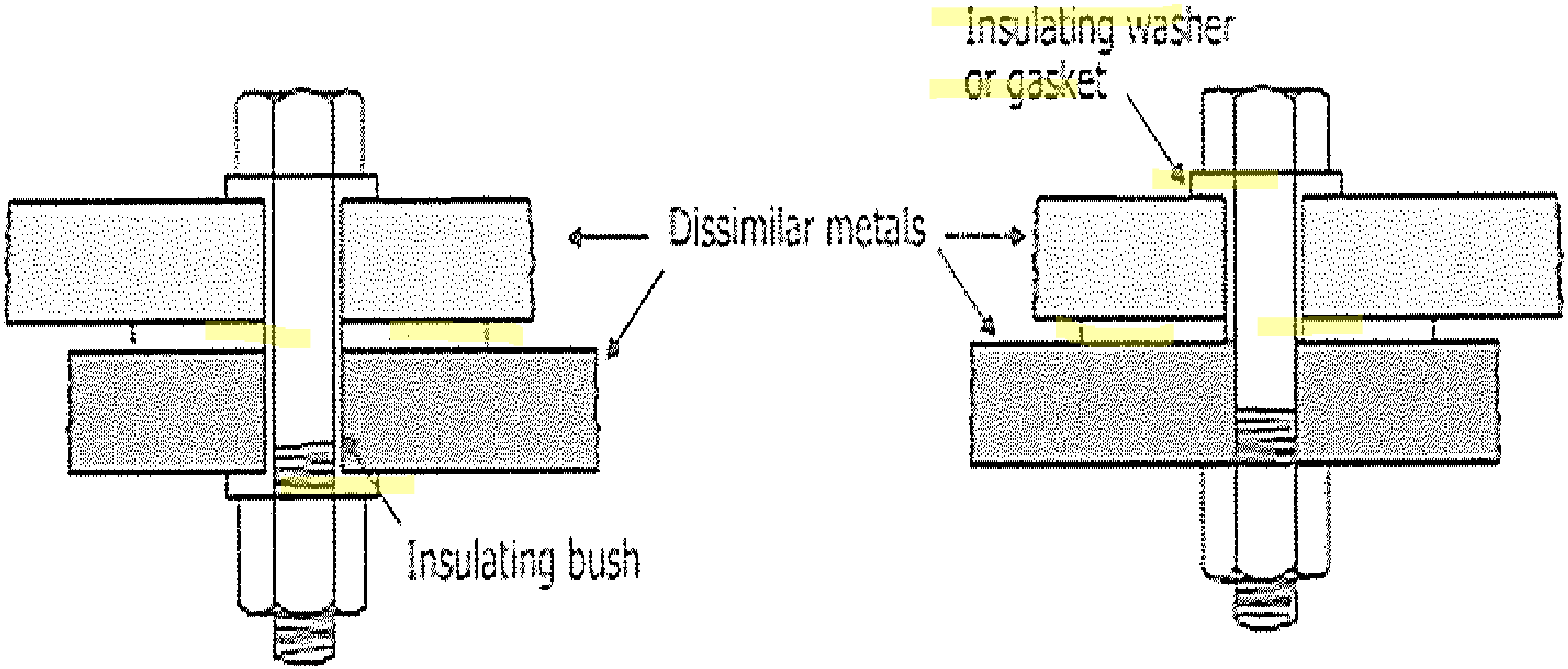



Figure 8.21b Preferred design features for joints. (By permission of SAE, Warrandale, PA, USA)

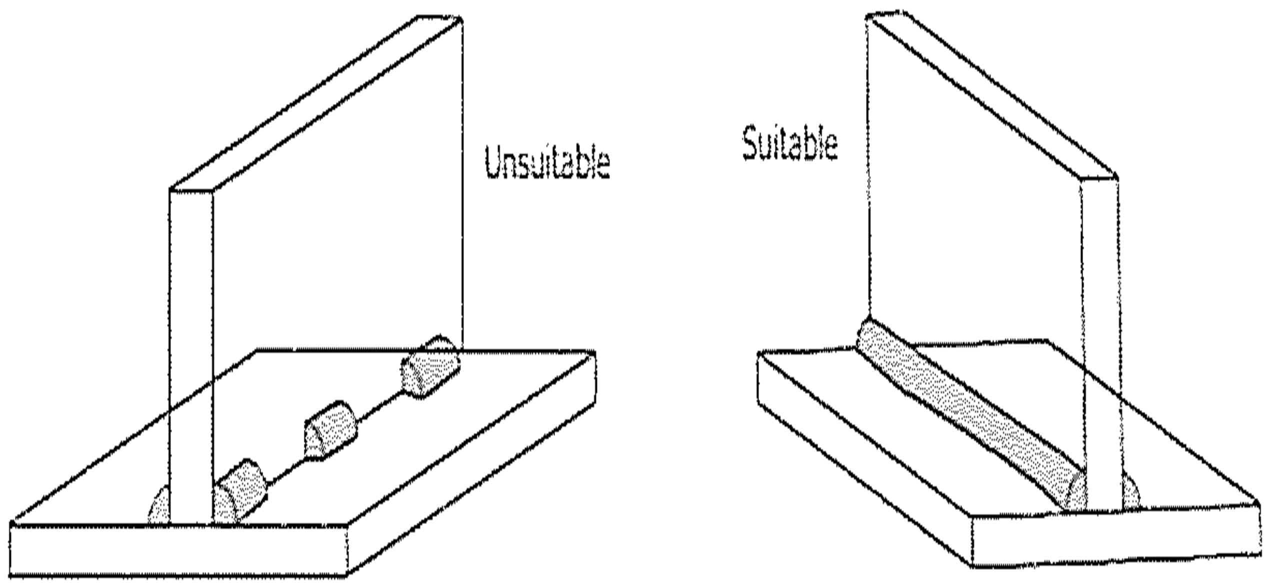



**Figure 8.20** Continuous and intermittent welds. (From Costa, W. (1985). *An Introduction to Corrosion and Protection of Metals*. Chapman and Hall, London. By kind permission of Chapman and Hall, London)

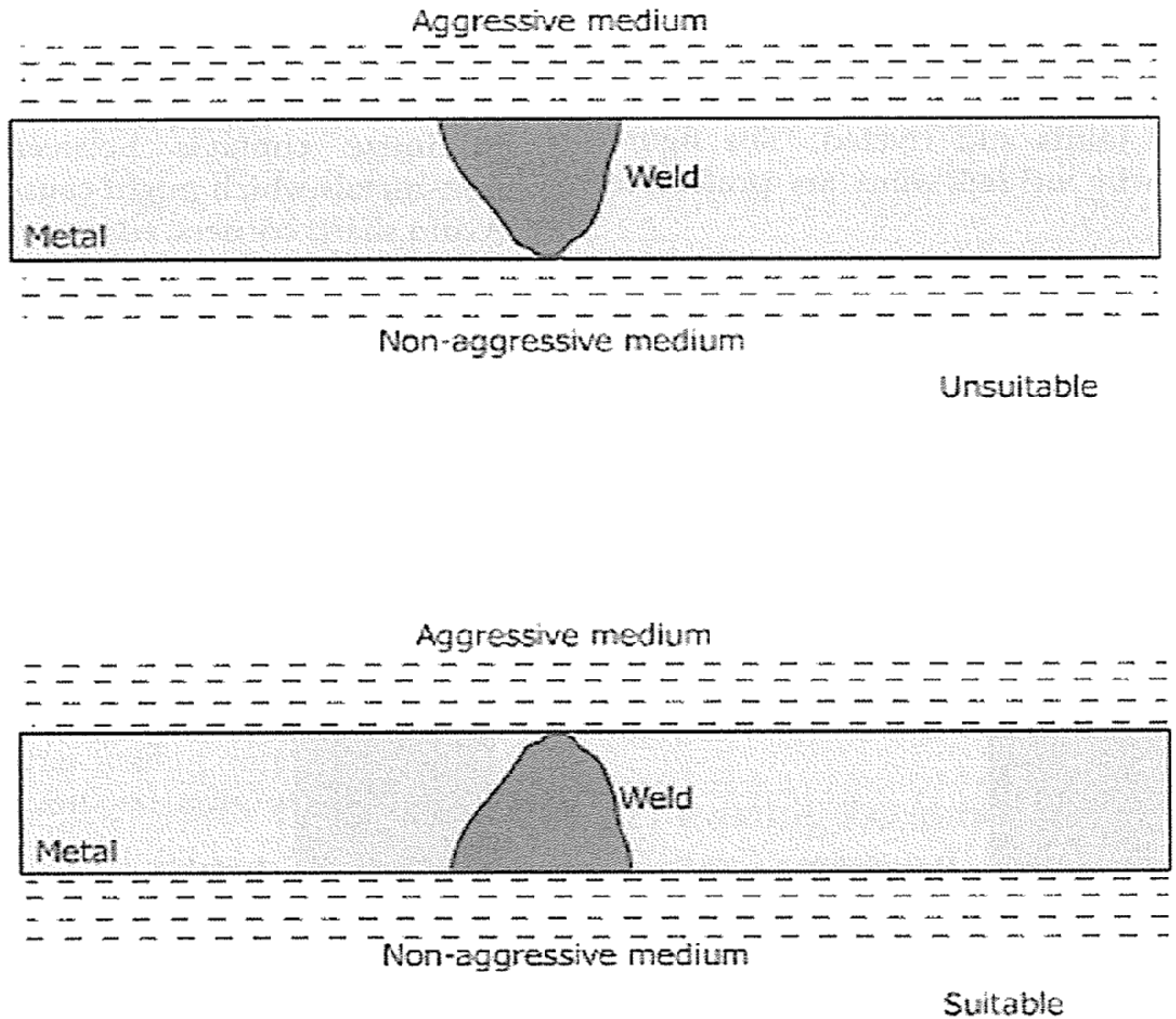



**Figure 8.22** The smaller side of the weld should be turned towards the aggressive medium

- **Figure 8.24 shows the suitability of soldering over threaded joints (Threaded forms differential aeration cells). Solder with more noble metal.**

- **Figure 8.25 shows comparison of spot welded joints and riveted. Welded joints are preferable to riveted.**

- **Use galvanized bolts and inhibitive primer when bolted joints are unavoidable.**

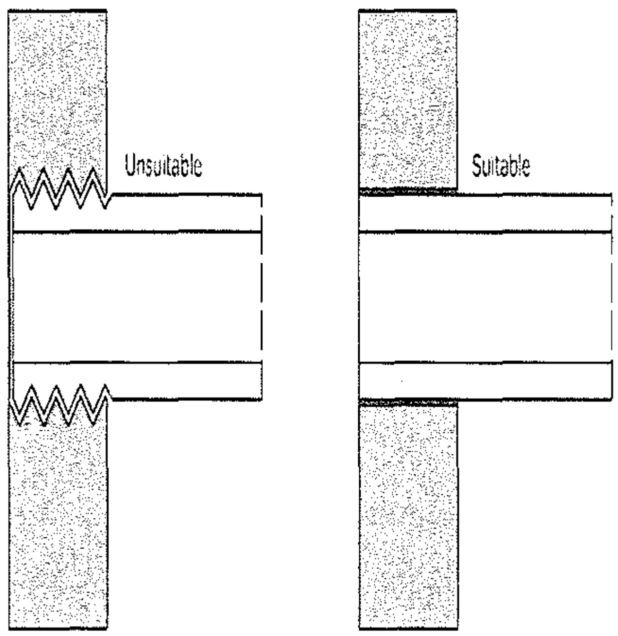



Figure 8.24 Soldering is to be preferred to threading. (From Costa, W. (1985). *An Introduction to Corrosion and Protection of Metals*. Chapman and Hall, London. Reproduced by kind permission of Chapman and Hall)

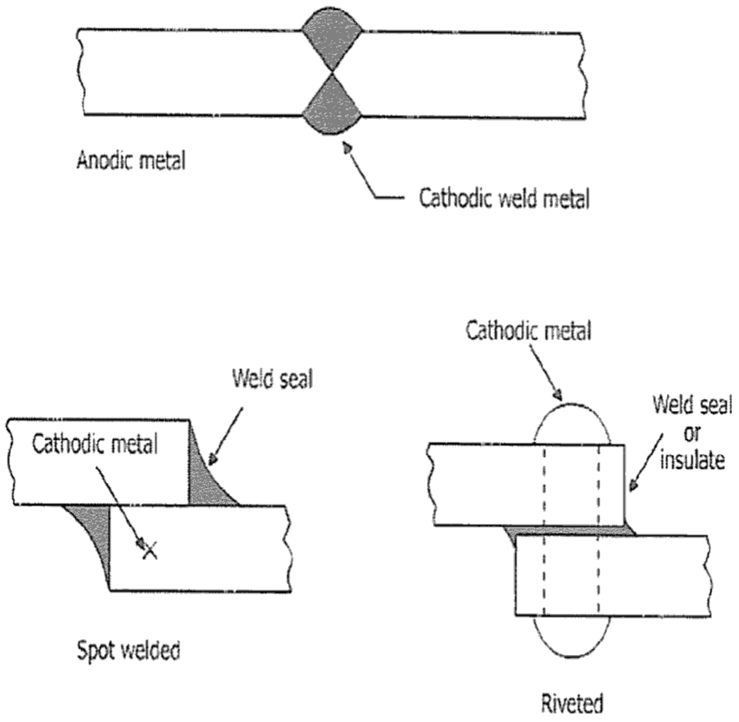



Figure 8.25 Comparison of welded joints and riveted joints. (From Rowe, L.C. (1977). GM Research Lab, Warren, MI, RPT24, Pub MR 2294 (GMR-3101-PCP (III) updated 1979). Reproduced by kind permission of GM, USA)

## FACTORS CONTRIBUTING TO POOR DESIGN

### 1- Ignoring Specifications

- There is a general trend to use PVC pipes in gas and water distribution systems.

- Concrete pipes have been used widely for water mains. There are specifications on soil compaction, the pressure the pipes can withstand, and the composition of soils.

  - **Non-adherence of these specifications lead to serious failures.**

- Copper pipes are joined in several instances with steel pipes *without proper insulation and coatings* which leads to service problems of galvanic corrosion.

# 2- Putting Dissimilar Pipes in the Same Trench

- Pipes of different materials, such as copper, mild steel and galvanized iron are often buried very close to each other in the same trench without any concern for galvanic corrosion.

  - The copper pipe is coated and insulated to minimize galvanic corrosion.
  - The mild steel pipe may be protected by a galvanic anode but this is not cost effective.

Note:

If two pipes are buried in a trench it is likely that they are bonded together with a metal strap somewhere, which will thus give a path for electrons and cause galvanic corrosion.

## 3- Insulation:

- Non-metallic couplings, unions and flange insulation are widely used for insulating against *bimetallic corrosion*.
- However, they are *not always wisely used.*
  a. All underground pipes must be insulated from the above-ground pipes.
  b. Insulators must be installed on distribution mains when connecting *new steel pipes to old steel pipes*, when connecting *steel to cast iron* and when installing a *newly coated pipeline* at every 2000 ft.
  c. When connecting a *copper service pipe to a steel main*, insulation is needed where the copper pipe connects with steel main pipe.
  d. No insulation is necessary when joining a plastic pipe to steel mains.

# Flowing Liquid Systems

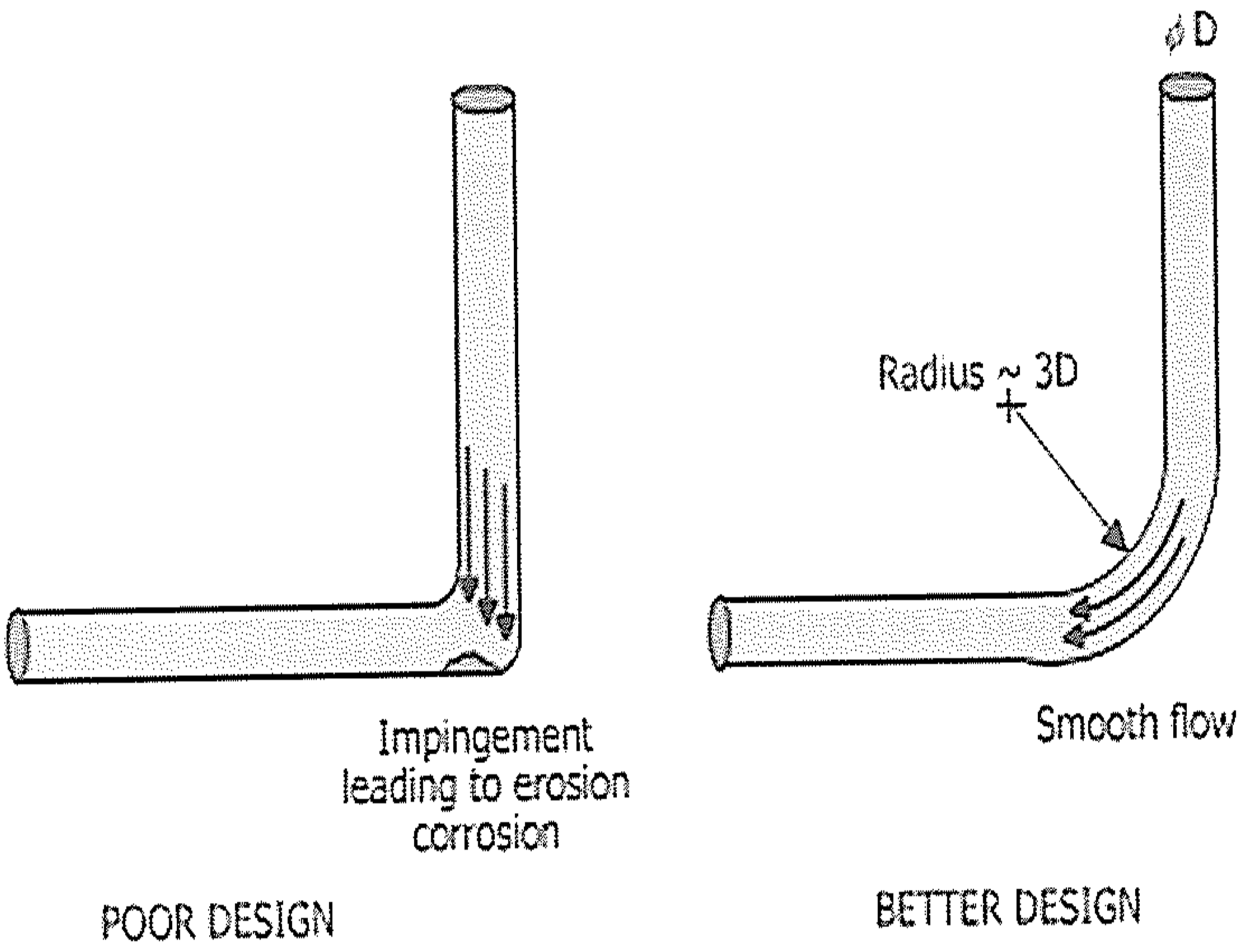



Figure 8.34a Larger radius is preferred for higher velocities in order to avoid erosion–corrosion

# Flowing Liquid Systems

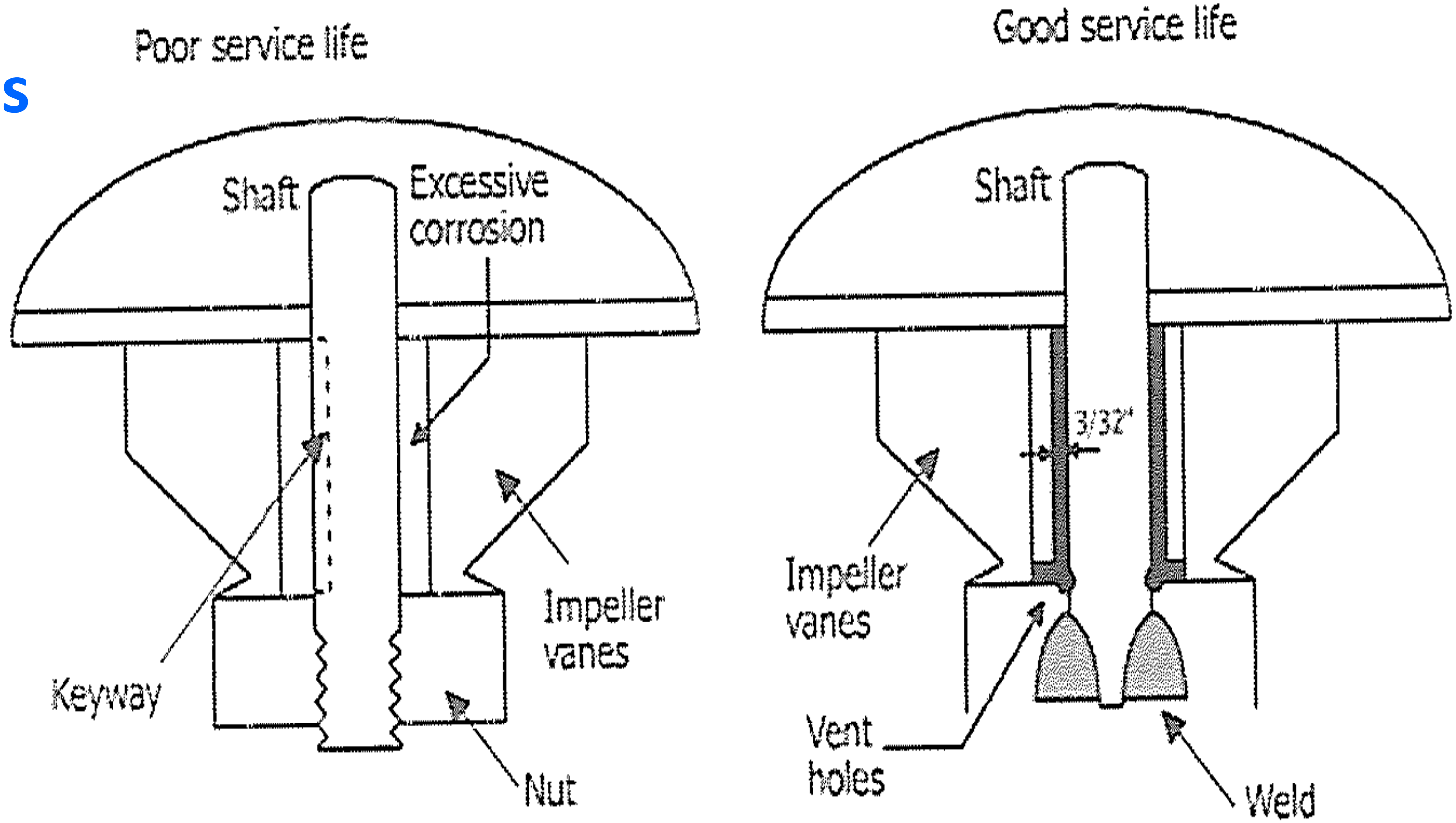



Figure 8.34b Impeller design

# ACCESSIBILITY FOR MAINTENANCE / PAINTING

- The design must be able to allow easy access to the areas requiring repair or maintenance.
- Appropriate long-life paints should be applied in areas which may not be accessible for a sufficient length of time.
- Figures 8.37 and 8.47 show access to areas suitable and unsuitable for maintenance (painting, etc.).
- A good design should allow uniform painting to be applied on the surface. Areas of uneven coating thickness are potential sites for initiation of corrosion.
- Figures 8.38a and b illustrate the point. For uniform coating application grind all sharp edges and apply an extra coat of paint. Keep sharp edges to a minimum.

# ACCESSIBILITY FOR MAINTENANCE / PAINTING

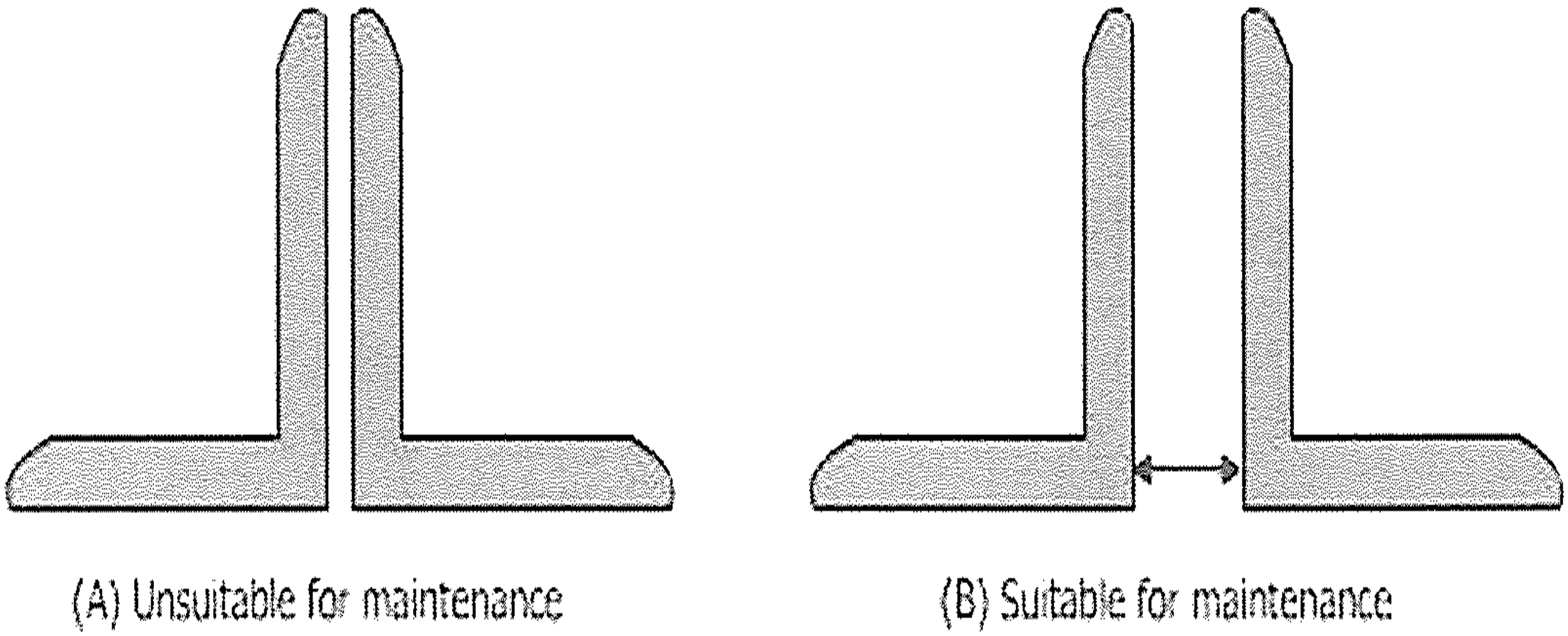



Figure 8.37 Design aspects with respect to accessibility for maintenance

## ACCESSIBILITY FOR MAINTENANCE / PAINTING

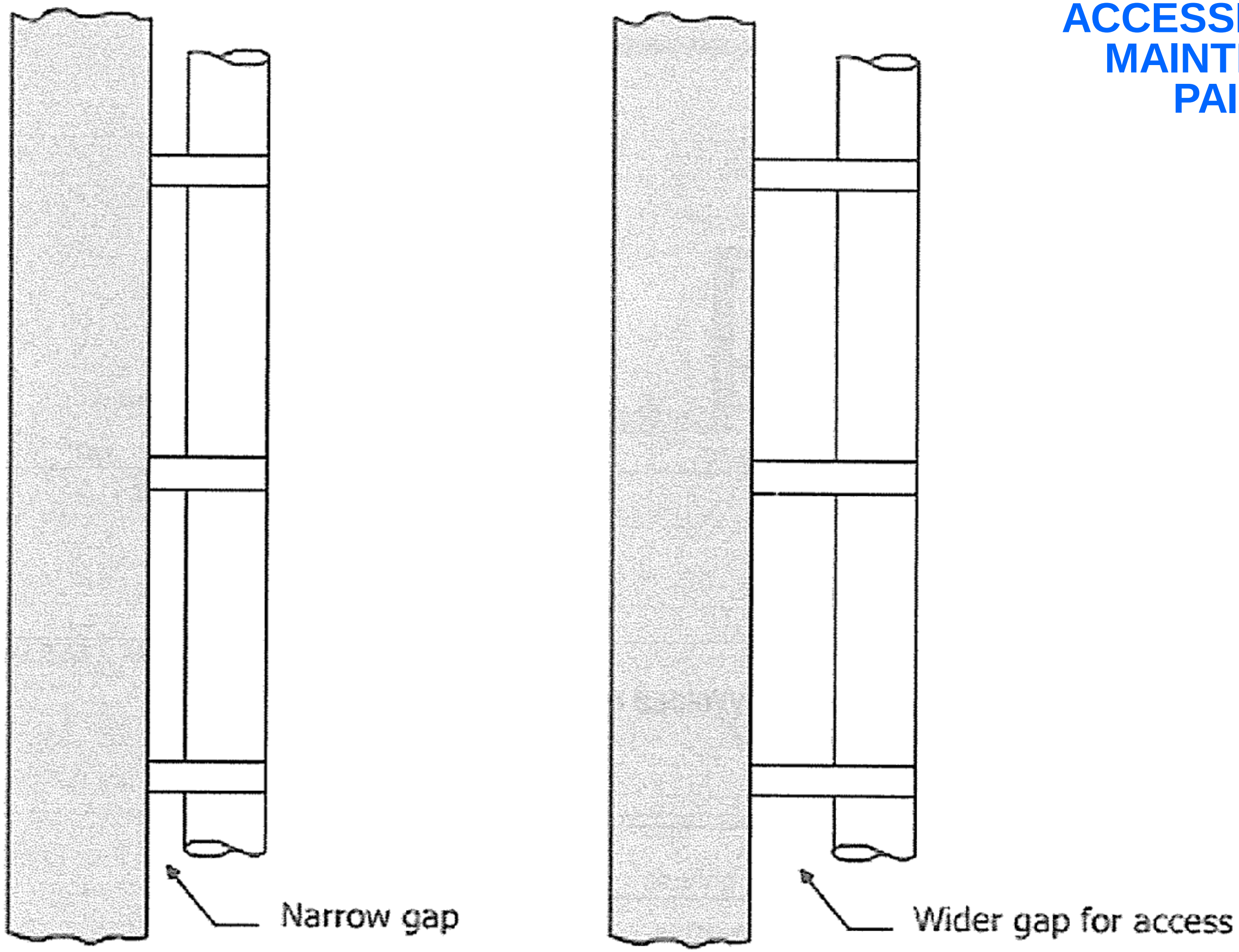



**Figure 8.47** Access for maintenance of pipes. (Chaldler, K. A. 1985. *Marine and offshore Corrosion*. Butterworth. By permission of SAE, Warrandale, PA, USA)

# ACCESSIBILITY FOR MAINTENANCE / PAINTING

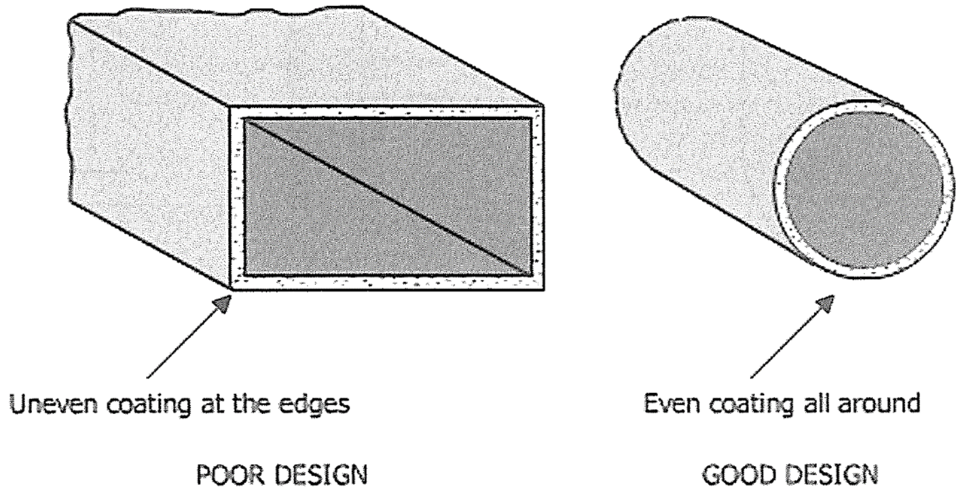



Figure 8.38a Design for uniform coating protection

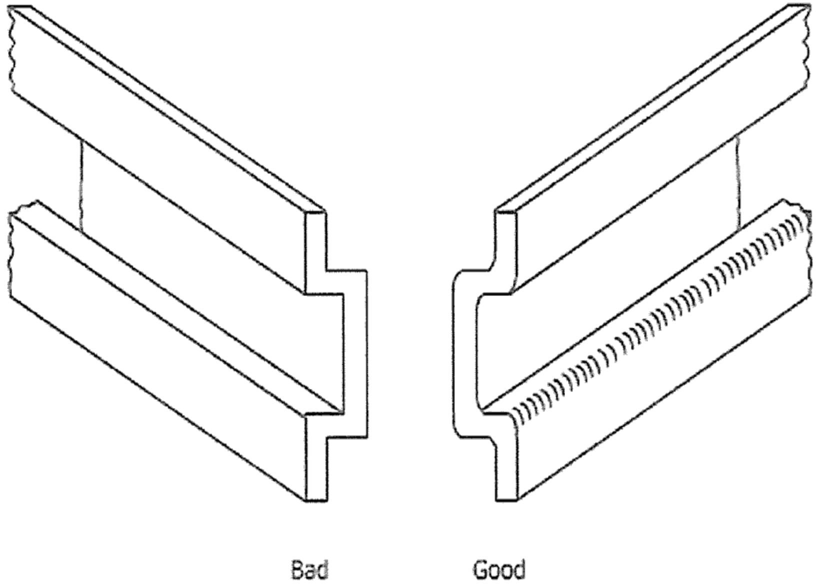



Figure 8.38b Suitability of designs for coating

# DESIGNS FOR LIQUID CONTAINERS

A good design for liquid container must offer the following:

a) Freedom from sharp corners and edges.

b) Smooth flow of liquid from the container.

c) Freedom from the buildup of water traps around the corners.

d) Complete drainage from the corners without any water traps.

The elimination of water traps is essential to minimize the formation of *differential oxygen cells* which lead to corrosion.

- As an operational matter, it is essential to remove water and dry out stainless steel tubing without delay as soon as leak testing of new water treatment plant is completed.
- There are many examples of *microbial corrosion* causing severe pitting of new plant soon after leak testing.

e) Minimizing of *bimetallic corrosion* by joining compatible materials without the risk of galvanic corrosion.

f) Complete internal and external coating of the containers, if cost effective.

# DESIGNS FOR LIQUID CONTAINERS

- Some of the above measures to prevent corrosion in liquid containers are shown in Fig. 8.39.
  - Figure 8.39(a) shows the best design because of the capability of the liquid containers for complete drainage and absence of water traps.
  - Figures 8.39 (b) and (c) are examples of bad design because of the incapability for complete drainage and presence of water and moisture traps around the corners.
  - Better designs are shown in Figures 8.39(d) and (e).

# DESIGNS FOR LIQUID CONTAINERS

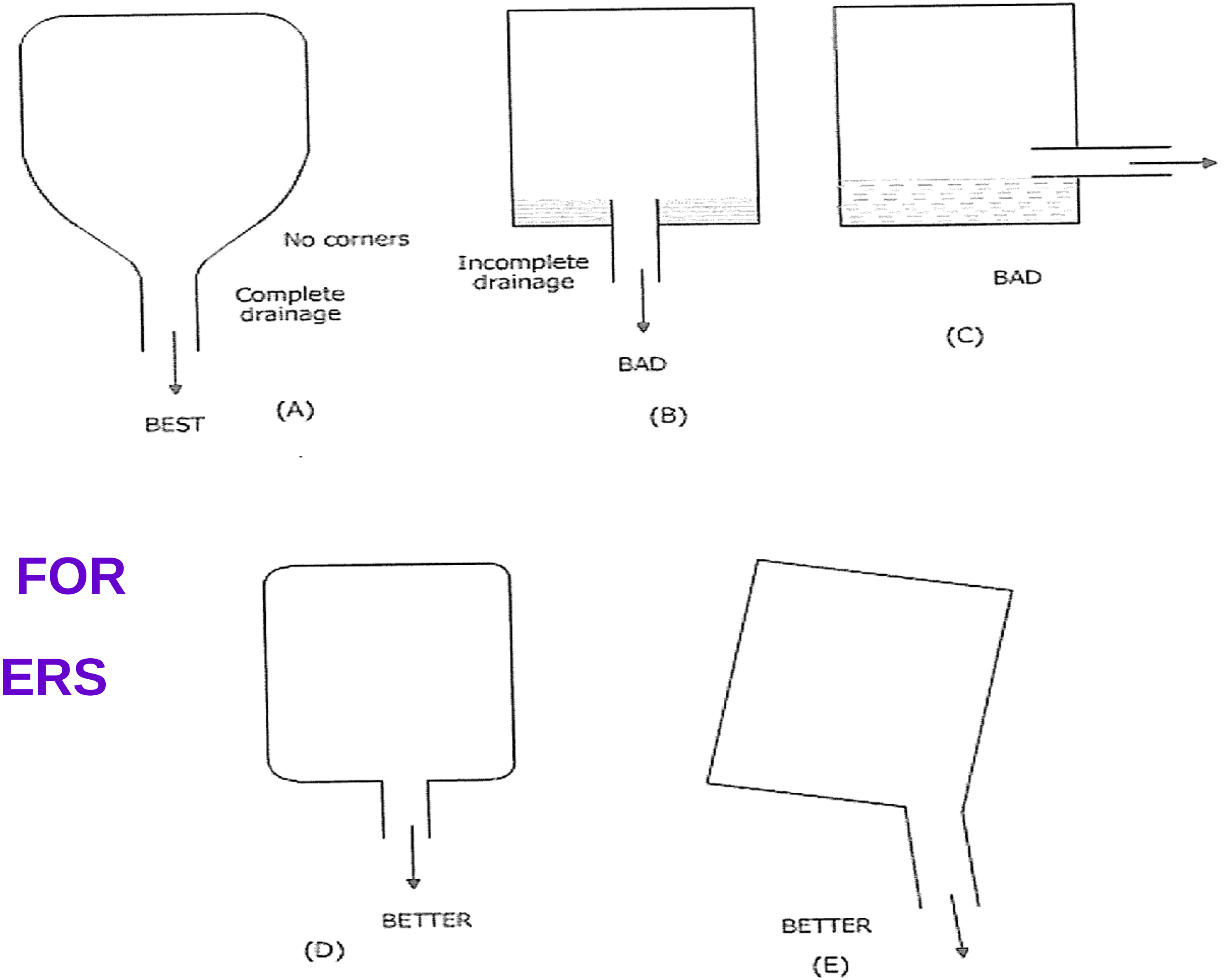
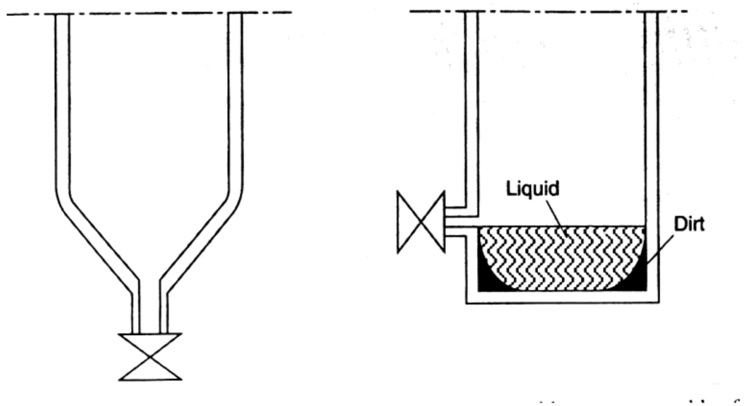
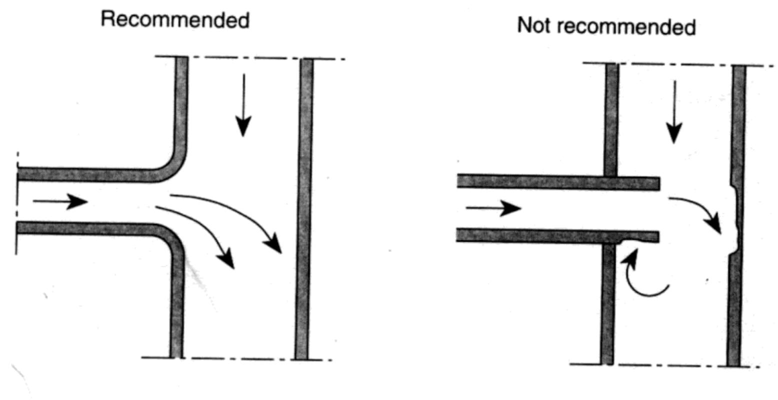


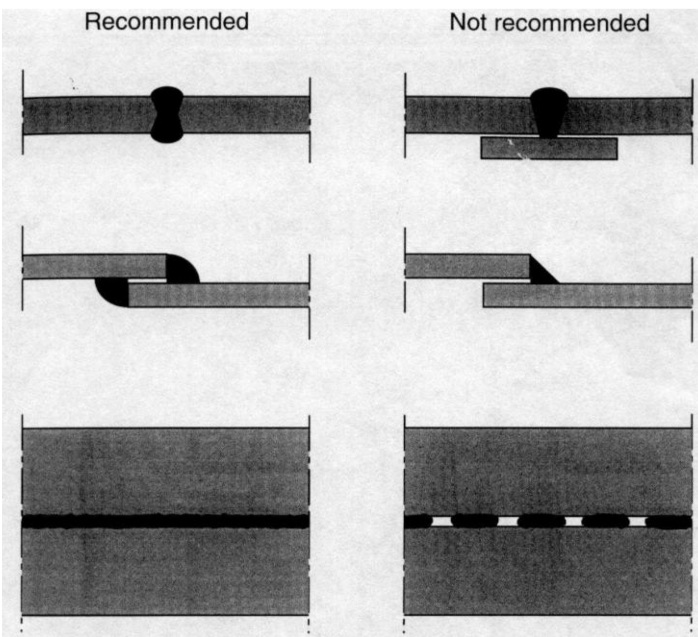

Figure 8.39 Good and bad designs for drainage

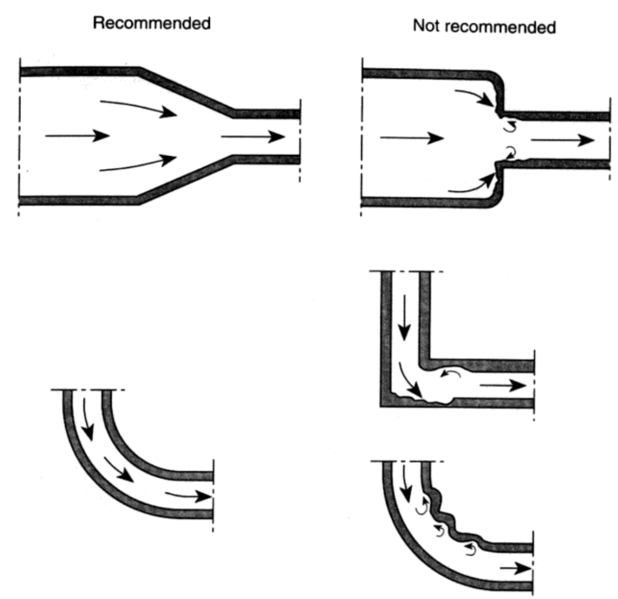
# Protection by Design Modifications




Recommended Not recommended



# DESIGNS FOR LIQUID CONTAINERS

Figure 8.40(a) shows a bad design because of the joining of a copper pipe with the galvanized steel tank.

– The copper ions may be plated on the surface of galvanized steel and lead to pitting.

– An aluminum inlet pipe joined to an aluminum tank would not cause galvanic corrosion (Fig. 8.40b).

– The design also offers a good drainage of the liquid. The design could be further improved by further smoothing the corners.

# DESIGNS FOR LIQUID CONTAINERS

A: bad design

B: good design

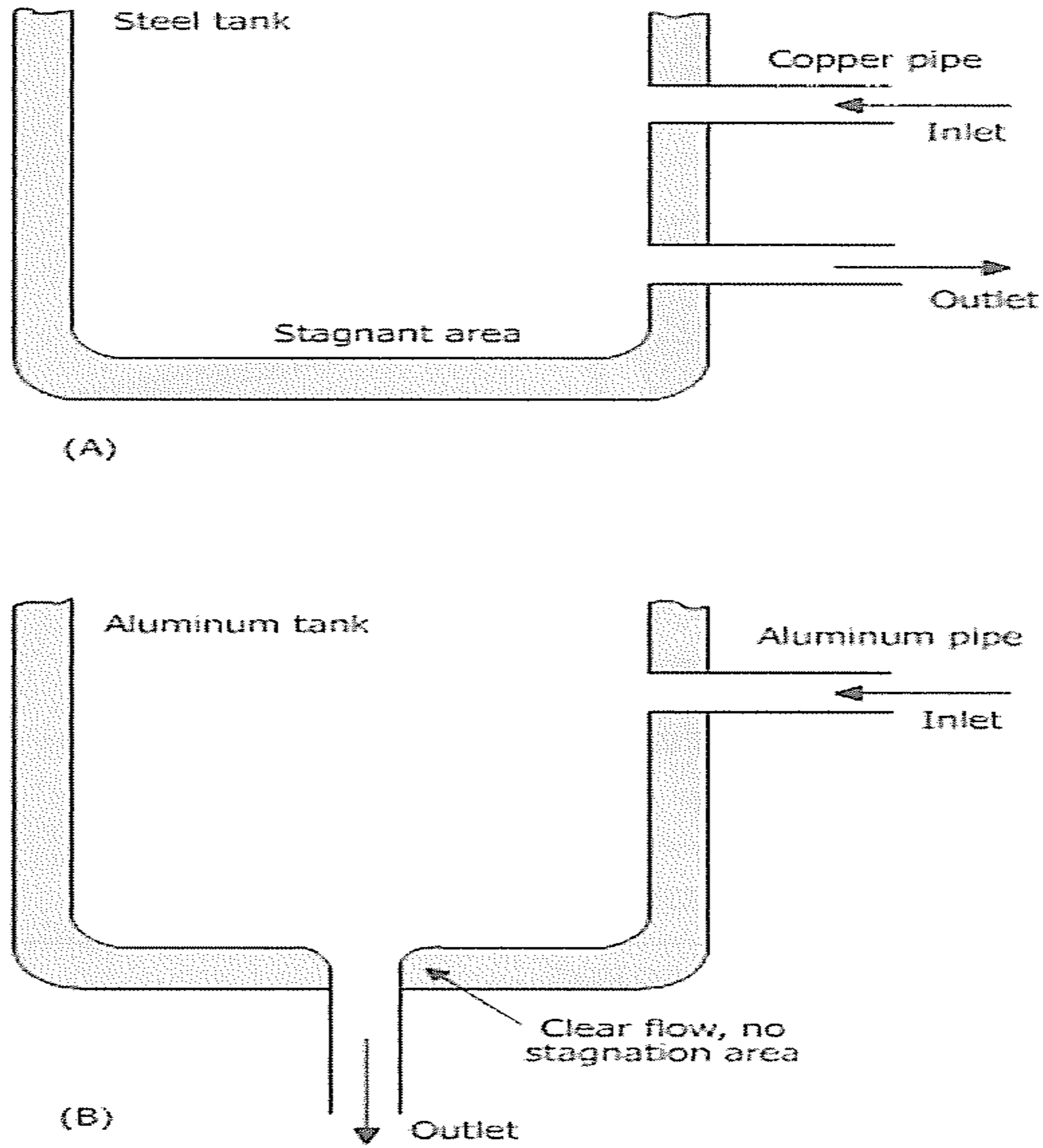



**Figure 8.40** Design for liquid containers

# Summary: General Design Rules

1. Provide allowance for corrosion in thickness.
2. Weld rather than rivet to avoid crevice corrosion.
3. Avoid dissimilar metals that can cause galvanic corrosion.
4. Avoid excessive stress and stress concentration.
5. Avoid sharp bends in pipes to prevent erosion corrosion.
6. Design tanks and containers for easy draining.
7. Design so that parts can be easily replaced.
8. Design heating systems so that hot spots do not occur.

# Design Do's & Don'ts

- Wall thickness – allowance to accommodate for corrosion effect.
- Avoid excessive mechanical stresses and stress concentrations in components exposed to corrosive mediums. Esp when using materials susceptible to SCC.
- Avoid galvanic contact / electrical contact between dissimilar metals to prevent galvanic corrosion.
- Avoid sharp bends in piping systems when high velocities and/or solid in suspension are involved – erosion corrosion.
- Avoid crevices – e.g weld rather than rivet tanks and other containers, proper trimming of gasket, etc.

# Design Do's & Don'ts

- Avoid sharp corners – paint tends to be thinner at sharp corners and often starts to fail.
- Provide for easy drainage (esp tanks) – avoid remaining liquids collect at bottom. E.g steel is resistant against concentrated sulfuric acid. But if remaining liquid is exposed to air, acid tend to absorb moisture, resulting in dilution and rapid attack occurs.
- Avoid hot spots during heat transfer operations – localized heating and high corrosion rates. Hot spots also tend to produce stresses – SCC failures.
- Design to exclude air – except for active-passive metals and alloys coz they require $O_2$ for protective films.
- Most general rule : AVOID HETEROGENEITY!!!