Experience over millions of robot operating hours in manufacturing industry has proved that robots can be both reliable and safe. Their reliability has been proven by demonstrating the ability to work for hour after hour, day after day, in hostile conditions. They do this with only the rare breakdown. When they do break down, as often as not their downtime is short, because diagnostic routines enable the maintenance workers to get them back on stream without delay. On a parallel with their reliability performance, robots have been proved safe: accidents involving injury to human beings are exceedingly unusual. Serious injury has never occurred. These impressive performance records in reliability and safety have been brought about by attention to design and by commonsense application of robots in use.

Environmental factors in robot systems

When equipment is designed for a specific purpose, such as a military application, it is usually possible to specify a set of environmental conditions surrounding the operation of that equipment. These conditions then form part of the design specification, and they play a large part in the choice of individual components, and in the layout and construction of the final hardware. Such is not the case for industrial robots. There is no single set of environmental conditions which covers all possible industrial possibilities. Nevertheless, after many millions of hours of industrial robot experience, it has been possible to come up with a design and quality test procedure that seems to have conquered the hazards presented by most known industrial environments. Test and design methods are, to some extent, empirical, and so will continue to evolve as more and more experience is gained.

Figure 5.1 lists the primary environmental factors that have to be considered in robot design. Because these conditions are described qualitatively, there may be merit in expanding upon this tabulation with even more qualitative discussion to give the would-be robot designer a ‘gut feeling’ for the job at hand.
1 Ambient temperature: up to 120°F without cooling air
2 Radiant heating: source temperature up to 2000°F
3 Shock: excursions up to ½ inch, repetitions to 2/second
4 Electrical noise: line drop-outs, motor starting transients; RF heating
5 Liquid sprays: water and other coolants, often corrosive
6 Fumes & vapors: process chemicals, steam cleaning
7 Particulate matter: sand, metallic dust, hot slag
8 Fire & explosion risk: open flame, explosive gas & vapor mixtures

**Figure 5.1 Hazards in the industrial environment**

**HEAT**
Ordinarily, a human worker is not required to function continuously in an ambient temperature over 120°F and therefore this is a reasonable maximum standard for an industrial robot. Both the human operator and the industrial robot are afforded cooling air if the workplace temperature exceeds 120°F. In some instances particular attention must be paid to radiant heating where the worker is the target of open furnaces, lehrs and hot parts in process. Radiation shields are sometimes used and a robot may expect to be provided with a curtain quench for its extremities.

**SHOCK AND VIBRATION**
There are not too many instances when an individual robot must endure severe vibration conditions. It is usually lugged to massive floor members and vibration from associated equipment is minimal. On the other hand, shock can be severe. Some hammer forge operations develop shock so severe that it can be felt in offices 300 yards away.

**ELECTRICAL NOISE AND INTERFERENCE**
One of the most frustrating environmental conditions to plague a robot designer is electrical noise. Designers have been unable to create a noise standard which would enable us to extrapolate in-house testing to noise immunity in the field. Any new design is put into the field in operations which we have found to be particularly ‘dirty’ as regards electrical noise.

An electrical line dropout that might cause a computation error in a computer, means only a burst of ‘garbage’ data output. For an industrial robot it might mean physical action damaging to the robot or to the equipment with which it is associated. Noise insensitivity is crucial and without a clear definition of the noise environment, design becomes an iterative process cycling back and forth between the field and the laboratory.

**LIQUID SPRAYS, GASES AND HARMFUL PARTICLES**
There are lots of things that land on or diffuse through industrial robots