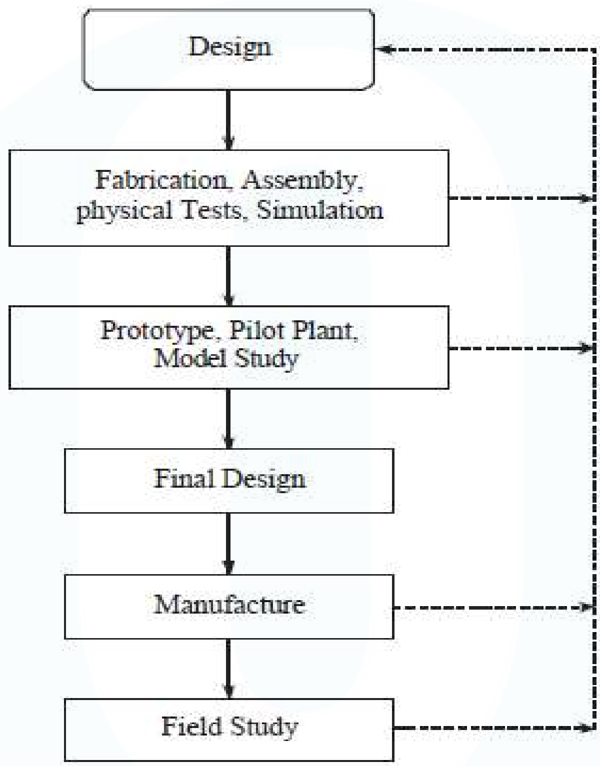
MODULE 3-ENGINEERING AS SOCIAL EXPERIMENTATION

ENGINEERING AS EXPERIMENTATION

Before manufacturing a product or providing a project, we make several assumptions and trials, designand redesign and test several times till the product is observed to be functioning satisfactorily. We trydifferent materials and experiments. From the test data obtained we make detailed design and retests.

Thus, design as well as engineering is iterative process as illustrated in Fig



Design as an interactive process

Several redesigns are made upon the feedback information on the performance or failure in thefield or in the factory. Besides the tests, each engineering project is modified during execution, basedon the periodical feedback on the progress and the lessons from other sources. Hence, the developmentof a product or a project as a whole may be considered as an experiment.

Engineering Projects VS. Standard Experiments

We shall now compare the two activities, and identify the similarities and contrasts.

A. Similarities

1. *Partial ignorance*: The project is usually executed in partial ignorance. Uncertainties exist inthe model assumed. The behavior of materials purchased is uncertain and not constant (thatis certain!). They may vary with the suppliers, processed lot, time, and the process used inshaping the materials

(e.g., sheet or plate, rod or wire, forged or cast or welded). There maybe variations in the grain structure and its resulting failure stress. It is not possible to collectdata on all variations. In some cases, extrapolation, interpolation, assumptions of linearbehavior over the range of parameters, accelerated testing, simulations, and virtual testingare resorted.

2. *Uncertainty*: The final outcomes of projects are also uncertain, as in experiments. Sometimes unintended results, side effects (bye-products), and unsafe operation have also occurred.

Unexpected risks, such as undue seepage in a storage dam, leakage of nuclear radiation froman atomic power plant, presence of pesticides in food or soft drink bottle, an new irrigationcanal spreading water-borne diseases, and an unsuspecting hair dryer causing lung cancer onthe user from the asbestos gasket used in the product have been reported.

3. *Continuous monitoring*: Monitoring continually the progress and gaining new knowledgeare needed before, during, and after execution of project as in the case of experimentation.The performance is to be monitored even during the use (or wrong use!) of the product bythe end user/beneficiary.

4. *Learning from the past*: Engineers normally learn from their own prior designs and inferfrom the analysis of operation and results, and sometimes from the reports of other engineers.But this does not happen frequently. The absence of interest and channels of communication,ego in not seeking information, guilty upon the failure, fear of legal actions, and merenegligence have caused many a failure, e.g., the Titanic lacked sufficient number of lifeboats—it had only 825 boats for the actual passengers of 2227, the capacity of the ship being3547! In the emergent situation, all the existing life boats could not be launched. Fortyyears back, another steamship Arctic met with same tragedy due to the same problem in thesame region. But the lesson was learned. In most of the hydraulic systems, valves had beenthe critical components that are least reliable. The confusion on knowing whether the valvewas open or closed, was the cause of the Three-Mile Island accident in 1979. Similarmalfunctioning of valves and mis-reading of gauges have been reported to have caused theaccidents else where in some power plants. But we have not learnt the lesson from the past.

The complacency that it will not happen again and will not happen 'to me' has lead to manydisasters.

B. Contrasts

The scientific experiments in the laboratory and the engineering experiments in the filed exhibit severalcontrasts as listed below:

1. *Experimental control*: In standard experiments, members for study are selected into twogroups namely A and B at random. Group A are given special treatment. The group B isgiven no treatment and is called the 'controlled group'. But they are placed in the sameenvironment as the other group A.This process is called the *experimental control*. This practice is adopted in the field ofmedicine. In engineering, this does not happen, except when the project is confined tolaboratory experiments. This is because it is the clients or consumers who choose the product,exercise the control. It is not possible to make a random selection of participants fromvarious groups. In engineering, through random sampling, the survey is made from amongthe users, to assess the results on the product. .

2. *Humane touch*: Engineering experiments involve human souls, their needs, views, expectations,and creative use as in case of social experimentation. This point of view is not agreed bymany of the engineers. But now the quality engineers and managers have fully realized thishumane aspect.

3. *Informed consent*: Engineering experimentation is viewed as Societal Experiment since thesubject and the beneficiary are human beings. In this respect, it is similar to medicalexperimentation on human beings. In the case of medical practice, moral and legal rightshave been recognized while

planning for experimentation. Informed consent is practiced inmedical experimentation. Such a practice is not there in scientific laboratory experiments.

Informed consent has two basic elements:
1. *Knowledge*: The subject should be given all relevant information needed to make thedecision to participate.
2. *Voluntariness*: Subject should take part without force, fraud or deception. Respect forrights of minorities to dissent and compensation for harmful effect are assumed here.
For a valid consent, the following conditions are to be fulfilled:
1. Consent must be voluntary
2. All relevant information shall be presented/stated in a clearly understandable form
3. Consenter shall be capable of processing the information and make rational decisions.
4. The subject's consent may be offered in proxy by a group that represents many subjectsof like-interests
Informed consent when bringing an engineering product to market, implies letting the customerknow the following: (*a*) the knowledge about the product (*b*) risks and benefits of using the product and (*c*) all relevant information on the product, such as how to use and how not touse (do's and don'ts). The relevant factual information implies, that the engineers are obligedto obtain and assess all the available information related to the fulfillment of one's moralobligations (i.e., wrong or immoral use of a product one designs), including the intendedand unintended impacts of the product, on the society. Still there exists a possibility of a large gap of understanding between the experimenter and the subjects public). Sometimes,the managements have not been willing to disseminate the full information about the projector product beyond the legal requirements, because of the fear of potential competitions andlikely exposure to potential litigation.

People object to *involuntary risks* wherein the affected individual is neither a direct participantnor a decision maker. In short, we prefer to be the subjects of our own experiments ratherthan those of somebody else. If it is an asbestos plant or nuclear plant to be approved,affected parties expect their consent to be obtained. But they are ready to accept *voluntary*risks as in the case of stunts and amazing races.

In case of Koodangulam power project as well as the Sethusamudram Canal Project, TamilNadu, several citizen groups including Fishermen Forums have responded. The Centralgovernment was able contain many harsh apprehensions and protracted legal and politicalbattles, by providing all relevant information.

4. *Knowledge gained*: Not much of new knowledge is developed in engineering experiments asin the case of scientific experiments in the laboratory. Engineering experiments at the mosthelp us to (*a*) verify the adequacy of the design, (*b*) to check the stability of the designparameters, and (*c*) prepare for the unexpected outcomes, in the actual field environments.

From the models tested in the laboratory to the pilot plant tested in the field, there aredifferences inperformance as well as other outcomes.

ENGINEERS AS RESPONSIBLE EXPERIMENTERS

Although the engineers facilitate experiments, they are not alone in the field. Their responsibility isshared with the organizations, people, government, and others. No doubt the engineers share a greaterresponsibility while monitoring the projects, identifying the risks, and informing the clients and thepublic with facts. Based on this, they can take decisions to participate or protest or promote.

The engineer, as an experimenter, owe several responsibilities to the society, namely,
1. A conscientious commitment to live by moral values.
2. A comprehensive perspective on relevant information. It includes constant awareness of theprogress of the experiment and readiness to monitor the side effects, if any.
3. Unrestricted free-personal involvement in all steps of the project/product development(autonomy).
4. Be accountable for the results of the project (accountability).

1 Conscientiousness

Conscientious moral commitment means: (*a*) Being sensitive to full range of moral values andresponsibilities relevant to the prevailing situation and (*b*) the willingness to develop the skill and putefforts needed to reach the best balance possible among those considerations. In short, engineers mustpossess open eyes, open ears, and an open mind (i.e., moral vision, moral listening, and moral reasoning).
This makes the engineers as social experimenters, respect foremost the safety and health of theaffected, while they seek to enrich their knowledge, rush for the profit, follow the rules, or care foronly the beneficiary. The human rights of the participant should be protected through voluntary and informed consent.

2 Comprehensive Perspective

The engineer should grasp the context of his work and ensure that the work involved results in onlymoral ends. One should not ignore his conscience, if the product or project that he is involved willresult in damaging the nervous system of the people (or even the enemy, in case of weapon development)
A product has a built-in obsolete or redundant component to boost sales with a false claim. Inpossessing of the perspective of factual information, the engineer should exhibit a moral concern andnot agree for this design. Sometimes, the guilt is transferred to the government or the competitors.
Some organizations think that they will let the government find the fault or let the fraudulent competitorbe caught first. Finally, a full-scale environmental or social impact study of the product or project by
individual engineers is useful but not possible, in practice.

3 Moral Autonomy

A detailed discussion is available in # 2.5. Viewing engineering as social experimentation, and anticipating
unknown consequences should promote an attitude of questioning about the adequacy of the existingeconomic and safety standards. This proves a greater sense of personal involvement in one's work.

4 Accountability

The term Accountability means:
1. The capacity to understand and act on moral reasons
2. Willingness to submit one's actions to moral scrutiny and be responsive to the assessment ofothers.
It includes being answerable for meeting specific obligations, i.e., liable to justify(or give reasonable excuses) the decisions, actions or means, and outcomes (sometimesunexpected), when required by the stakeholders or by law.
The tug-of-war between of causal influence by the employer and moral responsibility of theemployee is quite common in professions. In the engineering practice, the problems are:

(*a*) The fragmentation of work in a project inevitably makes the final products lie awayfrom the immediate work place, and lessens the personal responsibility of the employee.
(*b*) Further the responsibilities diffuse into various hierarchies and to various people. Nobodygets the real feel of personal responsibility.
(*c*) Often projects are executed one after another. An employee is more interested inadherence of tight schedules rather than giving personal care for the current project.
(*d*) More litigation is to be faced by the engineers (as in the case of medical practitioners).This makes them wary of showing moral concerns beyond what is prescribed by theinstitutions. In spite of all these shortcomings, engineers are expected to face the riskand show up personal responsibility as the profession demands.

CODES OF ETHICS

The ‘codes of ethics’ exhibit, rights, duties, and obligations of the members of a profession and aprofessional society. The codes exhibit the following essential roles:

1. *Inspiration and guidance*. The codes express the collective commitment of the profession toethical conduct and public good and thus inspire the individuals. They identify primary responsibilities and provide statements and guidelines on interpretations for the professionalsand the professional societies.
2. *Support to engineers*. The codes give positive support to professionals for taking stands onmoral issues. Further they serve as potential legal support to discharge professional obligations.
3. *Deterrence (discourage to act immorally)* and discipline (regulate to act morally). The codesserve as the basis for investigating unethical actions. The professional societies sometimesrevoke membership or suspend/expel the members, when proved to have acted unethical.This sanction along with loss of respect from the colleagues and the society are bound to actas deterrent.
4. *Education and mutual understanding*. Codes are used to prompt discussion and reflection onmoral issues. They develop a shared understanding by the professionals, public, and thegovernment on the moral responsibilities of the engineers. The Board of Review of theprofessional societies *encourages moral discussion for educational purposes*.
5. *Create good public image.* The codes present positive image of the committed profession tothe public, help the engineers to serve the public effectively. They promote more of selfregulation and lessen the government regulations. This is bound to raise the reputation of theprofession and the organization, in establishing the trust of the public.
6. *Protect the status quo*. They create minimum level of ethical conduct and promotes agreementwithin the profession. Primary obligation namely the safety, health, and welfare of thepublic, declared by the codes serves and protects the public.
7. *Promotes business interests*. The codes offer inspiration to the entrepreneurs, establish sharedstandards, healthy competition, and maximize profit to investors, employees, and consumers.

Limitations: The codes are not remedy for all evils. They have many limitations, namely:

1. General and vague wordings. Many statements are general in nature and hence unable tosolve all problems.
2. Not applicable to all situations. Codes are not sacred, and need not be accepted withoutcriticism. Tolerance for criticisms of the codes themselves should be allowed.

3. Often have internal conflicts. Many times, the priorities are clearly spelt out, e.g., codesforbid public remarks critical of colleagues (engineers), but they actually discovered a majorbribery, which might have caused a huge loss to the exchequer.
4. They can not be treated as final moral authority for professional conduct. Codes have flawsby commission and omission. There are still some grey areas undefined by codes. They cannot be equated to laws. After all, even laws have loopholes and they invoke creativity in thelegal practitioners.
5. Only a few enroll as members in professional society and non-members can not be compelled.
6. Even as members of the professional society, many are unaware of the codes
7. Different societies have different codes. The codes can not be uniform or same! Unifyingthe codes may not necessarily solve the problems prevailing various professions, but attemptsare still made towards this unified codes.
8. Codes are said to be coercive. They are sometimes claimed to be threatening and forceful.

Plagiarism

Plagiarism is presenting someone else's work or ideas as your own, with or without their consent, by incorporating it into your work without full acknowledgement. All published and unpublished material, whether in manuscript, printed or electronic form, is covered under this definition. Plagiarism may be intentional or reckless, or unintentional. Under the regulations for examinations, intentional or reckless plagiarism is a disciplinary offence.

The necessity to acknowledge others' work or ideas applies not only to text, but also to other media, such as computer code, illustrations, graphs etc. It applies equally to published text and data drawn from books and journals, and to unpublished text and data, whether from lectures, theses or other students' essays. You must also attribute text, data, or other resources downloaded from websites.

The best way of avoiding plagiarism is to learn and employ the principles of good academic practice from the beginning of your university career. Avoiding plagiarism is not simply a matter of making sure your references are all correct, or changing enough words so the examiner will not notice your paraphrase; it is about deploying your academic skills to make your work as good as it can be.

Forms of Plagiarism

Verbatim (word for word) quotation without clear acknowledgement

Quotations must always be identified as such by the use of either quotation marks or indentation, and with full referencing of the sources cited. It must always be apparent to the reader which parts are your own independent work and where you have drawn on someone else's ideas and language.

Cutting and pasting from the Internet without clear acknowledgement

Information derived from the Internet must be adequately referenced and included in the bibliography. It is important to evaluate carefully all material found on the Internet, as it is less likely to have been through the same process of scholarly peer review as published sources.

Paraphrasing

Paraphrasing the work of others by altering a few words and changing their order, or by closely following the structure of their argument, is plagiarism if you do not give due acknowledgement to the author whose work you are using.

A passing reference to the original author in your own text may not be enough; you must ensure that you do not create the misleading impression that the paraphrased wording or the sequence of ideas are entirely your own. It is better to write a brief summary of the author's overall argument in your own words, indicating that you are doing so, than to paraphrase particular sections of his or her writing. This will ensure you have a genuine grasp of the argument and will avoid the difficulty of paraphrasing without plagiarising. You must also properly attribute all material you derive from lectures.

Collusion

This can involve unauthorised collaboration between students, failure to attribute assistance received, or failure to follow precisely regulations on group work projects. It is your responsibility to ensure that you are entirely clear about the extent of collaboration permitted, and which parts of the work must be your own.

Inaccurate citation

It is important to cite correctly, according to the conventions of your discipline. As well as listing your sources (i.e. in a bibliography), you must indicate, using a footnote or an in-text reference, where a quoted passage comes from. Additionally, you should not include anything in your references or bibliography that you have not actually consulted. If you cannot gain access to a primary source you must make it clear in your citation that your knowledge of the work has been derived from a secondary text (for example, Bradshaw, D. Title of Book, discussed in Wilson, E., Title of Book (London, 2004), p. 189).

Failure to acknowledge assistance

You must clearly acknowledge all assistance which has contributed to the production of your work, such as advice from fellow students, laboratory technicians, and other external sources. This need not apply to the assistance provided by your tutor or supervisor, or to ordinary proofreading, but it is necessary to acknowledge other guidance which leads to substantive changes of content or approach.

Use of material written by professional agencies or other persons

You should neither make use of professional agencies in the production of your work nor submit material which has been written for you even with the consent of the person who has written it. It is vital to your intellectual training and development that you should undertake the research process unaided. Under Statute XI on University Discipline, all members of the University are prohibited from providing material that could be submitted in an examination by students at this University or elsewhere.

Auto-plagiarism

You must not submit work for assessment that you have already submitted (partially or in full), either for your current course or for another qualification of this, or any other, university, unless this is specifically provided for in the special regulations for your course. Where earlier work by you is citable, ie. it has already been published, you must reference it clearly. **Identical pieces of work submitted concurrently will also be considered to be auto-plagiarism.**

A BALANCED OUTLOOK ON LAW

The 'balanced outlook on law' in engineering practice stresses the necessity of laws and regulations andalso their limitations in directing and controlling the engineering practice. Laws are necessary because,people are not fully responsible by themselves and because of the competitive nature of the freeenterprise, which does not encourage moral initiatives. Laws are needed to provide a minimum level ofcompliance.

The following codes are typical examples of how they were enforced in the past:

Code for Builders by Hammurabi

Hummurabi the king of Babylon in 1758 framed the following code for the builders:
"If a builder has built a house for a man and has not made his work sound and the house which hehas built has fallen down and caused the death of the householder, that builder shall be put to death. Ifit causes the death of the householder's son, they shall put that builder's son to death. If it causes thedeath of the householder's slave, he shall give slave for slave to the householder. If it destroys property,he shall replace anything it has destroyed; and because he has not made the house sound which he hasbuilt and it has fallen down, he shall rebuild the house which has fallen down from his own property.
If a builder has built a house for a man and does not make his work perfect and the wall bulges, thatbuilder shall put that wall in sound condition at his own cost"

This code was expected to put in self-regulation seriously in those years.

Steam Boat Code in USA

Whenever there is crisis we claim that there ought to be law to control this. Whenever there is a fireaccident in a factory or fire cracker's store house or boat capsize we make this claim, and soon forget.Laws are meant to be interpreted for minimal compliance. On the other hand, laws when amended orupdated continuously, would be counter productive. Laws will always lag behind the technologicaldevelopment. The regulatory or inspection agencies such as Environmental authority of India can playa major role by framing rules and enforcing compliance.

In the early 19th century, a law was passed in USA to provide for inspection of the safety ofboilers and engines in ships. It was amended many times and now the standards formulated by theAmerican Society of Mechanical Engineers are followed.

Proper Role of Laws

Good laws when enforced effectively produce benefits. They establish minimal standards of professionalconduct and provide a motivation to people. Further they serve as moral support and defense for thepeople who are willing to act ethically.
Thus, it is concluded that:
1. The rules which govern engineering practice should be construed as of responsibleexperimentation rather than rules of a game. This makes the engineer responsible for thesafe conduct of the experiment.
2. Precise rules and sanctions are suitable in case of ethical misconduct that involves the violationof established engineering procedures, which are aimed at the safety and the welfare of thepublic.
3. In situations where the experimentation is large and time consuming, the rules must not tryto cover all possible outcomes, and they should not compel the engineers to follow rigidcourses of action.
4. The regulation should be broad, but make engineers accountable for their decisions, and
5. Through their professional societies, the engineers can facilitate framing the rules, amendwherever necessary, and enforce them, but without giving-in for conflicts of interest.

CASE STUDY: THE CHALLENGER

What happened?

The orbiter of the Challenger had three main engines fuelled by liquid hydrogen. The fuel was carriedin an external fuel tank which was jettisoned when empty. During lift-off, the main engines fire forabout nine minutes, although initially the thrust was provided by the two booster rockets. These boosterrockets are of the solid fuel type, each burning a million pound load of aluminum, potassium chloride,and iron oxide.
The casing of each booster rocket is about 150 feet long and 12 feet in diameter. This consists ofcylindrical segments that are assembled at the launch site. There are four-field joints and they use sealsconsisting of pairs of O-rings made of vulcanized rubber. The O-rings work with a putty barrier madeof zinc chromate.

The engineers were employed with Rockwell International (manufacturers for the orbiter andmain rocket), **Morton-Thiokol** (maker of booster rockets), and they worked for NASA. After many postponements, the launch of Challenger was set for morning of Jan 28, 1986. **Allan J. McDonald** wasan engineer from Morton-Thiokol and the director of the Solid Rocket Booster Project. He was skepticabout the freezing temperature conditions forecast for that morning, which was lower than the previouslaunch conditions. A teleconference between NASA engineers and MT engineers was arranged byAllan.
Arnold Thompson and **Roger Boisjoly**, the seal experts at MT explained to the other engineershow the booster rocket walls would bulge upon launch and combustion gases can blow past the O-rings of the field joints.

On many of the previous flights the rings have been found to have charred and eroded. Infreezing temperature, the rings and the putty packing are less pliable. From the past data gathered, attemperature less than 65 °F the O-rings failure was certain. But these data were not deliberated at thatconference as the launch time was fast approaching.

The engineering managers **Bob Lund** and **Joe Kilminster**agreed that there was a safety problem.Boisjoly testified and recommended that no launch should be attempted with temperature less than
53 °F. These managers were annoyed to postpone the launch yet again. The top management of MT wasplanning for the renewal of contract with NASA, for making booster rocket. The managers told BobLund "to take-off the engineering hat and put on your management hat". The judgment of the engineerswas not given weightage. The inability of these engineers to substantiate that the launch would beunsafe was taken by NASA as an approval by Rockwell to launch.
At 11.38 a.m. the rockets along with Challenger rose up the sky. The cameras recorded smokecoming out of one of the filed joints on the right booster rocket. Soon there was a flame that hit theexternal fuel tank. At 76 seconds into the flight, the Challenger at a height of 10 miles was totallyengulfed in a fireball. The crew cabin fell into the ocean killing all the seven aboard.

Moral/Normative Issues

1. The crew had no escape mechanism. Douglas, the engineer, designed an abort module toallow the separation of the orbiter, triggered by a field-joint leak. But such a 'safe exit' wasrejected as too expensive, and because of an accompanying reduction in payload.
2. The crew were not informed of the problems existing in the field joints. The principle ofinformed consent was not followed.
3. Engineers gave warning signals on safety. But the management group prevailed over andignored the warning.

Conceptual Issues

1. NASA counted that the probability of failure of the craft was one in one lakh launches. Butit was expected that only the 100000th launch will fail.
2. There were 700 criticality-1 items, which included the field joints. A failure in any one ofthem would have caused the tragedy. No back-up or stand-bye had been provided for these criticality-1 components.

Factual/Descriptive Issues

1. Field joints gave way in earlier flights. But the authorities felt the risk is not high.
2. NASA has disregarded warnings about the bad weather, at the time of launch, because theywanted to complete the project, prove their supremacy, get the funding from Governmentcontinued and get an applaud from the President of USA.
3. The inability of the Rockwell Engineers (manufacturer) to prove that the lift-off was unsafe. This was interpreted by the NASA, as an approval by Rockwell to launch.

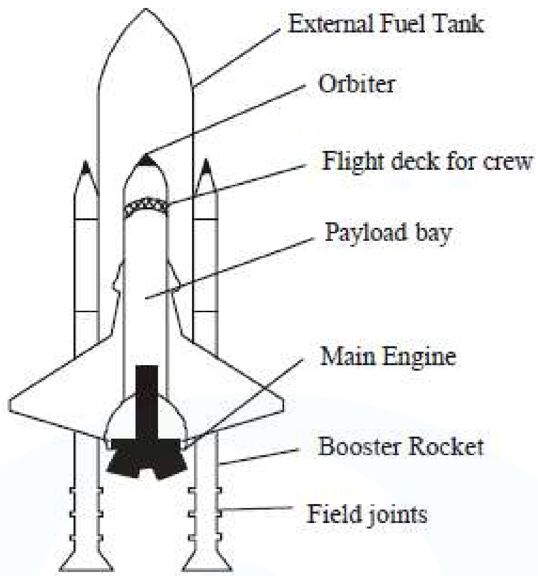


Fig. a Challenger

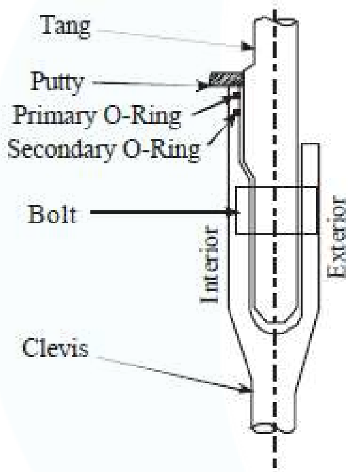


Fig. b Field joint before ignition

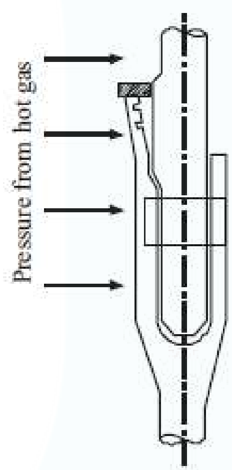


Fig. c Field joint after ignition

Bhopal Gas Tragedy

The Union Carbide had 51% and the Indian subsidiary UC India Ltd. had 49% of stock. In 1983, there were 14 plants in India manufacturing chemicals, pesticides, and other hazardous products. The Bhopalplant had a license to make Methyl isocyanate-based pesticides. In November 1984, they had decidedto close down the plant. For quite some years before the production rate was going down.

In the history of chemical plants disasters, three other wake-up calls were reported. Flixboroughaccident in 1974 in U.K. when certain modifications carried out in the plant led to the leakage andexplosion of *cyclohexane*, which killed 28 people. The Piper Alpha offshore oil platform disaster in

1988, near Scotland, killed 167 people and resulted in $ 2 billion losses. The third occurred in Toulouse,France in 2001, killing 29 people, and injuring thousands. A warehouse holding 300 tonnes of *ammoniumnitrate* fertilizer exploded and damaged 10000 buildings, including schools, a university, and a hospital.But we have not learnt from the past.

The cumulative effects of the following factors caused the tragedy in Bhopal on December 3,1984.

1. Maintenance was neglected and the trained maintenance personnel were reduced as economymeasure. Need for quick diagnosis aggravates the situation by causing considerablepsychological stress on the plant personnel.
2. Training activities for the supervisory personnel were stopped. This led to inadequate training of the personnel to handle emergencies.
3. Periodical Safety Inspection teams from U.S. which visited previously were also stopped. From the initial U.S. Standards, the safety procedures were reduced to low level Indianstandards. The procedures had been deteriorating at these sites for weeks or months, prior tothe accident. There was clear lack of management systems and procedures to ensure safety.
4. Vital spares for equipments and machineries were not available
5. Absence of capital replacement led to the stagnant economy of the plant.
6. The high turnover of the experienced engineers and technicians, who were demoralized bythe lack of development.
7. Lack of experienced personnel to operate and control the vital installations.
8. They have not conducted a thorough process hazards analysis that would have exposed theserious hazards which resulted in disaster later.
9. No emergency plan was put in practice, during the shut down and maintenance.
10. Above all, the commitment of top-level management to safety was lacking. They have beenpaying only lip service to safety of people of the host country.

Technologically, the tragedy was caused by a series of events listed:

1. The safety manual of Union Carbide prescribed that the MIC tanks were to be filled only upto 60% of the capacity. But the tanks were reported to have been filled up to 75%.
2. The safety policy prescribed that an empty tank should be available as a stand-bye in case ofemergency. But the emergency tank was also filled with to its full capacity. These factsconfirmed that the MNC had not followed and implemented appropriate safety standards ofthe home country in the host country. Can this be called as an example of 'misappropriatetechnology'?
3. The storage tanks should be refrigerated to make the chemical less reactive. But here therefrigeration system was shut down as an economy measure. This raised the temperature ofthe gas stored.
4. The plant was shut down for maintenance two months earlier. The worker who cleaned thepipes and filters connected to the tanks and closed the valves, was not trained properly. Hedid not insert the safety disks to prevent any possible leakage of the gas. This led to the buildup of temperature and pressure in the storage tanks.
5. When the gas started leaking out, the operators tried to use the vent gas-scrubber that wasdesigned to reduce the exhausting gas. But that scrubber was also shut down.
6. There was a flare tower that was designed to burn-off the gas escaping from the scrubber.That was not also in working condition.
7. The workers finally tried to spray water up to 100 feet to quench the gas (which is watersoluble). But the gas was escaping from the chimney of 120-feet high.
8. The workers were not trained on safety drills or emergency drills or any evacuation plans.