Online Instructor's Manual
to accompany

Quality Inspired Management: The Key to Sustainability

First Edition

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This manual provides "Mind Expanders" for chapters 3 through 11.

Mind Expanders to Test Your Understanding

Problem 3-1:

Harriett Harris has worked for the same company for 10 years. Due to the early and untimely death of her mother, Harriett did not have the opportunity to attend college, although she could have easily handled the demands of academe. Instead, she opted to go to work to support her two younger siblings. The local plant of Aztec Electronics readily employed her and trained her for their injector line, a critical process in the manufacture of electronic semiconductors. Harriett's job was to operate equipment that performs an important function in the manufacture of printed circuit boards, an operation where quality and yields are watched closely and play an important role in corporate profitability. Harriett takes pride in her work, always striving to do a good job. She has, over the years, become one of the most highly skilled and productive workers. Her job is highly specialized and requires only a few tasks, but each must be performed with great precision and close attention to detail.

Harriett's world has just been turned upside down. As a result of customer pressures on Aztec for just-in-time deliveries, the company has recently hired a consultant to help transform the manufacturing plant into one that supports cellular manufacturing. New social work groups have emerged. Harriett has been relocated from her line position, next to her friend Cathy, and placed in a work cell with people she does not know very well. She misses the daily chats with Cathy as they worked side-by-side on the line. She is now in this new group and has been told that her job responsibilities have changed in breadth and depth. She will have to undergo some intensive training and her performance will be based not only on her individual achievements but also on the collective performance of her work team. Harriett is frightened and has suddenly become overwhelmed by a sense of insecurity. Like an anchor she feels that the tide of anxiety and frustration is slowly pulling her under. "Coming to work used to be such fun—now I dread it and look forward to the weekends."

a. How could Harriet's management have anticipated what impact the change in Harriet's job responsibilities might have on her as a person and the quality of her future contributions to Aztec Electronics?

   It is difficult to know how individual workers will react to changes in job requirements. What motivates one may instill fear in another. Management should make every effort to determine to what extent the culture is ready for sweeping reforms. As the organization strives to become an HPWO, it is essential that management understand the growth needs of each of workers at an individual level. Those with low growth needs should be the target for extra training, mentoring, and the assignment of small assignments of increasing responsibilities to build confidence and self-esteem.

b. If the employees, including Harriet, are defined as a valued stakeholder group, what could Aztec management do differently in managing change so that the needs of these stakeholders are considered?

   Change should not be mandated from above, if the change requires support and participation by those farther down the chain. Aztec has a lot invested in Harriet and Harriet has in turn invested much of herself for the welfare of the company. She should not have been abruptly placed in a new social work situation without participating in that decision. Her managers should have had enough empathy to have been able to predict the results. The move may have been necessary but there was no process by which Harriet could transition from the old to the new. With the current state of affairs it is unlikely that Harriet will be successful in her new job.

c. Assuming that Aztec is able to identify good employees such as Harriett who do not wish to have their jobs enriched, and do not wish to be empowered, how should they resolve this issue if their intended changes are aimed at greater decentralization, a flatter organizational structure, and more autonomy at the work interface?

   Empowerment, when properly implemented, is self-management and self-determination. Most humans like to have control over their own behaviors and would prefer not having someone riding herd on their every move and telling them what to do. However, all Harriet can see is the accountability aspect – she is afraid of failure and having to shoulder the blame for any problem that arises. Management can turn this around by embracing the workforce as equal partners and establishing rewards and recognition that provides equitable and generous rewards when things go well and minimizes any punishments when things do not go so well.

Problem 3-2:
Dennis Mitchell is the plant manager of a company in northern Alabama that produces interiors for luxury yachts. The ethnicities of his workforce are mixed: about 40% are white, 25% African American, 15% Hispanic, 10% Libyan, and 10% Asian (Korean, Chinese, and Vietnamese). As for gender breakdown, 60% are women. Twenty percent either do not speak English at all or they have very poor English conversational skills. His departmental supervisors report that they have grave difficulty in giving orders and having those orders carried out.

Lately the business has been in a downturn. A soft economy together with growing foreign competition has had a serious effect on sales. As a result, last week Dennis reluctantly had to cancel one of the three production shifts and lay off 70 workers. The plant is one of the primary employers for a small town of 15,000 and the layed-off workers have little prospects of gaining work locally. That incident only exacerbated an already volatile workplace environment. Just last month, when Dennis expanded the duties of the sewing room foreperson to include the cut-out department, the workers downed their tools and walked off the job. The threatening language they used at the time gave Dennis cause to believe some intended to physically damage the property so he summoned the local sheriff's department for protection. That inflamed the group more and it took some skillful negotiating on the part of an independent mediator to calm things down and get the workers to return.

Responding to pressures from stockholders the company CEO is concerned about sustainability, and is now pressuring Dennis to turn things around. Dennis would like to adopt a more participatory style of management, but is not certain how to go about it, particularly since he perceives that there is a lack of trust between management and labor.

a. What are some of the principal issues that need to be articulated before this company can begin to build a new workplace culture? That is, if you were summoned to this plant as a consultant, what are the first and most important questions that you would need answered?

   The company needs to begin to repair labor-management relations. This will be a slow and possibly painful process and management needs to be willing to listen and respond to the concerns of workers. As a consultant I would establish a list of questions and, using those questions, I would interview each and every non-management worker to identify any pervasive issues or concerns. I would then develop a set of questions for management and would interview each manager individually. All interviews would be private, independent, and kept strictly confidential. When all the data has been analyzed, depending on the most pressing issues, and those that can be dealt with positively to bring about short-term change, I would recommend appropriate measures, drawn from the Chapter 3 material, aimed at improving workers' status, self-worth, and sense of ownership. A plan for implementation would need to be mapped out with and agreed by Dennis and his management team.

b. In building a supportive culture how can this company overcome the language barrier? How can it begin to build trust between management and the employees?

   The language barrier is a tough one but is only one of the ethnicity issues when an organization has a diverse workforce. Good communications are essential to creating and maintaining efficient workflow. Management should show an interest in these non-English languages and a willingness to learn some key terms that relate to production, but expressed in the workers' respective native tongues. The company could also sponsor English classes and could develop a system of visual controls that would be clearly understood by everyone (i.e. communications in pictures rather than words).

c. How could the team structure be used to advantage in an environment like this?

   Teams could be formed initially with the express purpose of facilitating communications. These team settings could provide the forum for the exchange of language knowledge concerning important key terms and for developing and disseminating knowledge on visual communication aids.

d. How could the management of this company use its human resources to help it gain competitive advantage?

   Like many other companies this one operates in competitive markets and uses processes that are labor intensive. Therefore human resource management is key to competitive success and creating value for financial stakeholders. The company needs to consider ways in which its workforce can feel a sense of shared ownership. Management needs to think of its human component as assets, not costs. They can begin by reviewing the compensation scheme and also take a look at its non-pay (fringe) benefits. It may be wise to let the workforce participate in decisions to expand these benefits – such as starting up a child-care facility or permitting shared jobs or flexible work arrangements. Perhaps compensation could be tied to profitability using incentive pay schemes or gainsharing.

e. If the company does find it necessary to downsize, how do you think its approach would differ under these two perspectives:

   i. Losing personnel is like writing off assets on the company balance sheet.

      Under this perspective managers would view the loss of personnel in much the same way as if they had to suddenly write the value of inventory off of the company books (i.e. write it down to zero value). This is a more agonizing decision than under the second perspective below because management can see how the decision to let people go adversely affects the company's balance sheets (not that the value of human capital ever explicitly shows up there but this is the mindset). With this in mind, management is more likely to try and weather the storm during bad times rather than let valued employees go. Under this perspective there is an inherent recognition that the organization has made a substantial investment in each individual and that it is important to protect and grow the investment for future returns.

   ii. Losing personnel is like shedding costs from the company profit and loss statement.

      Under this perspective bad times get better by reducing the cost of human resources; a strategy that immediately shows up as an improvement on the firm's profit and loss statement. Pink slips can be handed out on the basis of seniority or sheer numbers where entire divisions are cut. This approach does not take into account the intrinsic cost of losing valuable expertise, which may go over to the competition. This approach also treats the organization's investment in the personnel who are let go as a sunk cost, not relevant to the downsizing decision.

Problem 3-3:
Define some of the outcomes of HRM as an open system. How can feedback be used to improve these outcomes? How would these outcomes be measured?

In Chapter 2 we made the system differentiation between an output and an outcome. Outputs can be directly attributed to and measured at the exit point of a system’s value stream. Figure 3-2 suggests that system outputs can be categorized as existing either in the production or the affective domain. Those that reside in the affective domain are more like outcomes than outputs. These would include such attributes as loyalty, respect, pride, morale, and initiative. We could also include attributes like learning, growth, and expertise from the production domain. Measures of outcomes will for the most part be subjective and the value of some of these will evolve over an entire career. Learning, expertise, and growth are closely related and can be at least partially measured indirectly through an employee’s contribution to the outputs of those value streams where they have task assignments. Attributes like pride, initiative, and loyalty must rely on subjective observation as to how well the employee “fits” into the culture, how well he/she interacts with others, and his overall attitude towards the organization and his/her work.

Problem 3-4:
Place yourself in the position of someone who has just been hired to help an organization move toward an HPWO. You find that the workforce is diverse, and, after testing the employees, you find that many of them have low growth needs. You also find that they mistrust management. What would you do?

An HPWO is characterized by empowerment, continual learning, employee participation, knowledge-sharing, and performance-based and equitably administered rewards. Before an organization can become an HPWO the work culture has to be cabable of change. Participation and empowerment are important characteristics of an HPWO, but low growth needs and mistrust present barriers to moving forward with an ambitious implementation plan. As for where to start, there are two issues that should be tackled initially. First, the culture must start to move towards establishing a trust relationship between management and employees. Management plays a critical role here. The consultant could start by trying to determine (through interviews and surveys, for example) the reasons why the employees fail to trust that management tells them the truth and/or does not look out for their best interests. Perhaps the communications system needs to be looked at so that an open and frank exchange of information between management and the workforce can begin. The consultant could work closely with the senior leadership to identify some specific actions that could be taken to demonstrate to the workers that management is willing to listen to them and respond positively to their needs. In addition, on a limited basis, management could establish a process that would enable workers to input and/or have representation in the strategic planning process.
On the second issue (growth needs) it is important that growth needs be taken into account in job assignments and also in employee development. Under the consultant’s supervision a comprehensive job analysis should be performed, computing the motivating potential score (MPS) for each job. This will help to determine a job-matching scheme that will support the goals of an HPWO. In addition, those employees with low growth needs could be identified as candidates for development (e.g. deliberately mixing low and high growth needs employees on the same team).

Problem 3-5:
Imagine that you are working in a small factory that makes high-end cabinets, built-in bookcases, and mantels. The work has been organized so that a team of workers performs all of the operations, such as cutting, milling, sanding, gluing, and staining on a family of similar products. Although similar, all products are distinct in that they are custom made for customers and will typically be installed in residential homes. The workers within the team all have multiple skills in all of the operations necessary. How would a team such as this operate if it were an SMWT? How would it differ as an SDWT? Explain.

As a self-managed work team (SMWT) each team would be empowered to develop whatever methods and procedures within the group that the team feels are best (for it) in order to achieve the team's goals that are handed to them from upper management. Each team would be able to schedule time within the group, approve time off, evaluate performance, and administer rewards and punishments as permitted under the broad guidelines and parameters established by management. By contrast, if each team were a self-directed work team (SDWT), it would operate with almost total autonomy as a small company, being able to set its own objectives, policies, and procedures. An SDWT can make decisions on compensation, hiring and firing, and purchasing. For a small cabinet factory, it is unlikely the concept of establishing SDWT's would be feasible.

Problem 3-6:
Place yourself in a top leadership position in the following organizations. What steps could you take to create a sense of shared ownership on the part of your employees?

a. Large discount retailer, like Target or Walmart

   Possibilities include stock options, gainsharing, team building, special privileges and recognition (e.g. employee of week, reserved parking), flexible working arrangements, provision of family-friendly services (e.g. child care, fitness center), job rotation, job enrichment, and employee discounts.

b. Large, publicly traded company that manufactures computers

   Possibilities include stock options, gainsharing, team building, special privileges and recognition, flexible working arrangements, flexible job descriptions family-friendly services, job rotation, job enlargement, job enrichment, employee discounts, permission to take computing equipment home, provision of technical support for home computers, access to internet and networking, flexible job descriptions, and employee discounts.

c. Small, privately owned bake shop

   Possibilities include profit-sharing, special privileges and recognition, flexible working arrangements, job rotation, job enrichment, employee discounts, and team-building.

d. Hotel chain

   Possibilities include profit-sharing, travel discounts, special privileges and reognition, family-friendly services, flexible working arrangements, job rotation, job enlargement, job enrichment, and team-building activities.

e. Government agency

   Possibilities include family-friendly services, flexible working arrangements, job rotation, job enlargement, job enrichment, flexible job descriptions, and team-building.

f. Airline

   Possibilities include travel discounts, profit-sharing, family-friendly services, flexible working arrangements, job enrichment, and team-building.

g. School system

   Possibilities include family-friendly services, flexible working arrangements, special privileges and recognition, team-building, and job enrichment.

Problem 3-7:
Consider each of the organizations listed in problem 3-6. To what extent do you believe the employees can be empowered? As a senior leader, how would you empower them?

Large discount retailer – flatten the organization and push decision-making authority downward. Performance metrics should hold decision makers accountable but should include generous rewards for good performance.

Computer manufacturer – flatten organization structure, establishing production teams or cells; delegate decision-making to teams and hold team accountable for results. Teams will need training in decision-making and problem solving and should be equitably rewarded for meeting or exceeding goals.

Small bake shop – permit employees to make certain decisions especially in dealing with customers and resolving any customer service issues. Be generous with praise for good performance and use below par performance as a training opportunity to improve.

Hotel chain – Empower employees who deal directly with the public with the authority to resolve most problems that arise so that customer satisfaction is ensured. Employees must be made aware of the limits of this authority beyond which they must seek guidance from upper management; within the limits management must be prepared to support employee decisions and appropriately reward and recognize their contributions to improved customer satisfaction.

Government agency – Assign employees to teams that have the authority to make decisions and execute action plans. Teams will have to be provided resources (e.g. a budget) and empowered to allocate those resources as the team deems necessary.

Airline – Ticket, gate agents, and air crew should be given the authority to make decisions on the spot on behalf of customers to resolve issues and take care of the interest of passengers.

School system – Similar to a government agency, employees in the school system can be empowered through team-building. In the classroom teachers can be given authority and flexibility in lesson plans, teaching methods, and class activities. Teachers can also be empowered to speak with authority with parents and know that the school system will support them in the decisions they make and positions they take.

Problem 3-8:
How does a team differ from a club (e.g., a service club like Rotary)? How does a team differ from a committee? Explain.

A club can be a team, or can include teams, as can a committee. However, a collection of people bound together with a single over-arching purpose (e.g. service, finance, recruitment) does not mean that that group is a team and will behave as one. An effective team is unified in purpose and acts as if it were a super-being – the whole being greater than the sum of its parts and having developed a team mind where collectively the group can make decisions that everyone owns and supports. There is a team-building process that all groups must go through in order to transform a collection of people into a team and the process is evolutionary. This process requires the team to evolve through three stages – establishing a team identity, building team conceptual skills, and finally developing the capability for team self monitoring.

Problem 3-9:
For each of the following teams, indicate whether the team is self-managed, self-directed, neither self-managed nor self-directed, or not a team at all.

a. College football team

The best teams are partially though not entirely self-managed. The coach sets the goals and parameters, which the team must abide by. The team then has much autonomy to pull together and achieve the common set of goals. How great the team is can depend on how well the team is able to coalesce as one and develop and execute plays well.

b. School debating team

Self-managed. They have no say on their debate topic, but once given can within the group develop and execute competitive debating strategies.

c. First-response emergency team

Self-directed. First responders must be empowered to make on-the-spot decisions and carry those decisions out. Lives and property could be lost if emergency crews need to go through an approval hierarchy to do their jobs.

d. U.S. diplomatic negotiating team

Self managed. The goals are set outside the team and, within the parameters set, the team is empowered to make decisions and negotiate with foreign dignitarie

e. International consulting group

The consulting group will assign a team to a specific project and for that project the team will be self-directing – setting its own agenda, working autonomously with its client to set goals, acquiring and deploying resources, etc.

f. Surgical team

A surgical team would not satisfy the criteria for either a SMWT or SDWT. The goal is predetermined (i.e. save a life, restore health, etc.) and the chief surgeon is clearly the leader who must lead in an autocratic manner. Every member of the team has a job to do and knows how to do it but awaits instructions from the surgeon to perform as required.

g. U.S. Army brigade infantry forward combat team

In a combat situation there must be a clear team leader and all other members of the team must strictly and without hesitation follow his orders. Therefore combat teams are neither SMWT's or SDWT's.

h. Cockpit crew of a Boeing 747 aircraft

Under normal operations the cockpit crew would operate as an SMWT. However, in a crisis situation the captain would take charge and the team would cease to operate in a collaborative mode.

i. NASCAR pit crew

The pit crew operates like a SDWT. The crew is free to make decisions on strategy, staffing, performance, methods, etc. to support the racecar driver and minimize the number and duration of pit stops.

Problem 4-1:

Interpret each of the following tolerance frames.

a.

⌖	Ø 0,5	A

Referenced circular or cylindrical component should be positioned 0.5mm relative to Datum plane A.

b.

⏥	0,05

Referenced surface should be contained between two parallel planes 0.05mm apart.

c.

∠	0,1	A

The axis of referenced component must lie between two parallel planes 0.1mm apart inclined at the specified angle relative to Datum plane A.

d.

//	0,2	A	B

The referenced component must lie between two planes 0.2mm apart that are parallel to Datum planes A and B.

e.

↗	0,1	A

The radius of the referenced circular component must fit within a zone that is 0.1mm wide relative to a Datum point (origin) A.

Problem 4-2:

A certain production process produces two parts: a bearing and a shaft. In the final assembly the shaft and bearing are randomly mated and a critical specification is the clearance between the two parts. The distribution of the inside diameters of the bearing is normally distributed with a mean equal to 5.40 mm with a standard deviation of 0.735 mm. The distribution of the outside diameters of the shaft is normally distributed with a mean equal to 3.93 mm with a standard deviation of 0.413 mm.

a. Estimate the mean and variance of the distribution of clearances for the bearing-shaft assemblies.

$$\mu_{clearance} = \mu_{bearing} - \mu_{shaft}$$
$$\mu_{clearance} = 5.40 - 3.93 = 1.47$$
$$\sigma^2_{clearance} = \sigma^2_{bearing} + \sigma^2_{shaft} = (0.735)^2 + (0.413)^2 = 0.540 + 0.171 = 0.711$$
$$\sigma_{clearance} = 0.843$$

b. Assuming that the mating of bearings and shafts is random estimate the proportion of assemblies that will not fit together. (*Hint:* The assemblies will not fit together if the clearance is less than or equal to zero.)

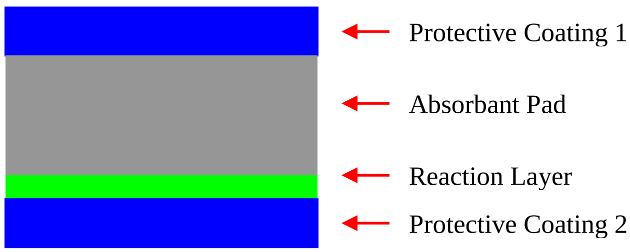
$$z = \frac{0 - 1.47}{0.843} = -1.74$$
$$\Phi(-1.74) = 0.0409 \Rightarrow 4.09\% \text{ will not fit together}$$

c. By how much would the variance in clearances have to be reduced so that the proportion of defective assemblies is less than 1%?

$$z = \frac{0 - 1.47}{\sigma_{new}} = -2.33$$
$$\sigma_{new} = \frac{-1.47}{-2.33} = 0.631$$
$$\sigma^2_{new} = 0.398$$
$$\% \text{ decrease } = \left(\frac{0.711 - 0.398}{0.711}\right)(100) = 44.02\%$$

Problem 4-3:

The research and development team of a medical device manufacturer is designing a new diagnostic test strip to detect the breath alcohol level. The materials are assembled as shown in the following figure.



Production data for each of the four components is summarized in the following table. All measurements are in millimeters.

	Materials			
	Protective Coating 1	**Absorbant Pad**	**Reaction Layer**	**Protective Coating 2**
Mean	9.972	49.775	4.979	7.964
Standard Deviation	2.007	9.692	0.988	0.958
Distribution Shape	Normal	Normal	Normal	Normal

a. Compute an estimate of the mean and variance of the thickness of assembled strips.

$$\mu_{Total} = \mu_1 + \mu_{pad} + \mu_{reaction} + \mu_2 = 9.972 + 49.775 + 4.979 + 7.964 = 72.690$$
$$\sigma^2_{Total} = \sigma_1^2 + \sigma^2_{pad} + \sigma^2_{reaction} + \sigma_2^2 = 4.028 + 93.935 + 0.976 + 0.918 = 99.857$$
$$\sigma_{Total} = 9.993$$

b. Assuming random assembly, what is the probability that the thickness of a strip, selected at random will exceed 75 mm?

$$z_u = \frac{75 - 72.690}{9.993} = 0.23$$
$$\Phi(0.23) = 0.409 \Rightarrow 40.9\%$$

Problem 4-4:

A food processor manufactures a certain canned vegetable that has a printed label weight of 305 gm. The specifications for the net contents in each can are 305 gm $\pm$ 10 gm. Individual cans are randomly selected from the end of the filling line, after sealing, and weighed. These are gross weights and reflect the weight of the empty cans, the lids, and the processed vegetable contents. The gross weights are in a state of statistical control with an average of 324.1 gm and a standard deviation of 4.5 gm. The cans and lids come from a supplier who provides data that shows that the processes producing these components is in statistical control with a process average and standard deviation for the cans of 15 gm and 2 gm, respectively; and for the lids the average and standard deviation are 3 gm and 0.3 gm, respectively.

a. Estimate the average and standard deviation of net weights of this canning operation.

$$\mu_{net} = \mu_{gross} - \mu_{cans} - \mu_{lids} = 324.1 - 15 - 3 = 306.1$$
$$\sigma^2_{net} = \sigma^2_{gross} - \sigma^2_{cans} - \sigma^2_{lids} = 20.25 - 4 - 0.09 = 16.16$$
$$\sigma_{net} = 4.02$$

b. Assuming a normal distribution, what percentage of the canning process is producing cans that are overweight (i.e., above the upper specification limit)? What percentage is underweight?

$$z_u = \frac{315 - 306.1}{4.02} = 2.21$$
$$\Phi(2.21) = 0.0136 \Rightarrow 1.36\% \text{ overweight}$$
$$z_l = \frac{295 - 306.1}{4.02} = 2.76$$
$$\Phi(2.76) = 0.0029 \Rightarrow 0.29\% \text{ underweight}$$

c. Assuming that the average of the canning operation can be brought to and controlled at the target weight of 305 gm, by what percentage would the variance of the gross fill weights have to be reduced so that the average fills are 3.5 standard deviations away from each specification limit? Assume that the variances of the cans and lids remain the same.

$$z_u = \frac{315 - 305}{\sigma_{net}} = 3.5$$
$$\sigma_{net} = \frac{10}{3.5} = 2.86$$
$$\sigma^2_{gross} = \sigma^2_{net} + \sigma^2_{cans} + \sigma^2_{lids} = (2.86)^2 + 4 + 0.09 = 12.27$$
$$\% \text{ decrease } = \left(\frac{16.16 - 12.27}{16.16}\right)(100) = 24.07\%$$

Problem 4-5:

For each of the following identify an appropriate device to measure the dimension indicated.

a. Diameter of a hole

   Inside calipers, a bore gauge, a go/no go gauge, or a coordinate measuring machine

b. Depth of a keyway slot

   Depth micrometer gauge (commonly referred to simply as a depth gauge); otherwise a go/no go gauge could be used if the specific dimensional measurement is not required, or a coordinate measuring machine.

c. To sort out shaft diameters in a production lot that are outside specification limits

   Go/no go gauge

d. Distance between the center of a hole and a particular edge of a part

   Divider calipers or coordinate measuring machine

e. Thickness of a silicon wafer

   Micrometer; there are specialized versions of micrometers available for this purpose called thickness gauges

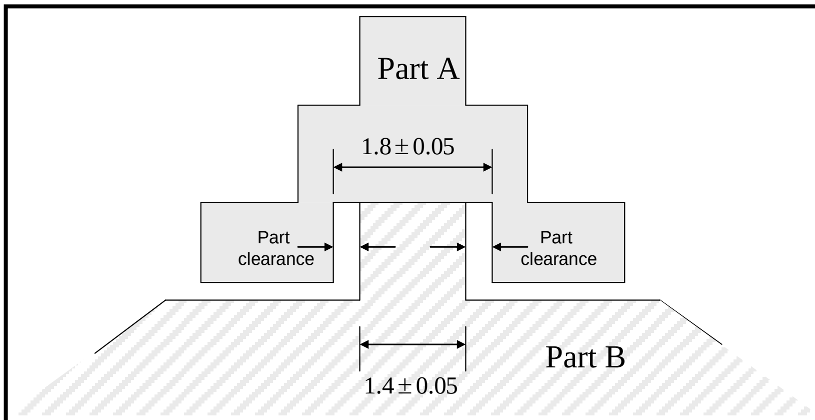
f. Threads on a pipe

   Thread gauge

g. Small, critical clearance between contacts in an electronic controller

   Feeler gauge

Problem 4-6:
Two machined parts must be assembled as shown in the diagram below. To function properly a clearance must be maintained between the two parts. The critical dimension on Part A has specifications of 1.8 ± 0.05 and the critical dimension on Part B has specifications of 1.4 ± 0.05 as indicated. The design engineers have specified that the clearance on each side be 0.2 ± 0.05. Production data indicates that for Part A the average dimension is 1.790 with a standard deviation of 0.0189; for Part B the average dimension is 1.406 and a standard deviation of 0.0220.



Tolerances for Machined Parts Assembly

a. Assuming a normal distribution, what proportion of the production of Part A is outside the specification limits? Above the upper specification limit? Below the lower specification limit?

$$z_u = \frac{1.85 - 1.79}{0.0189} = 3.17$$

$$\Phi(3.17) = 0.000762 \Rightarrow 0.076\% \text{ out of spec on high side}$$

$$z_l = \frac{1.75 - 1.79}{0.0189} = -2.12$$

$$\Phi(-2.12) = 0.0170 \Rightarrow 1.7\% \text{ out of spec on low side}$$

b. Assuming a normal distribution, what proportion of the production of Part B is outside the specification limits? Above the upper specification limit? Below the lower specification limit?

$$z_u = \frac{1.45 - 1.406}{0.0220} = 2$$

$\Phi(2) = 0.0228 \Rightarrow$ 2.28% out of spec on high side

$$z_l = \frac{1.35 - 1.406}{0.0220} = -2.55$$

$\Phi(-2.55) = 0.0054 \Rightarrow$ 0.54% out of spec on low side

c. Approximately what proportion of the distribution of clearances will lie outside specification limits? Above the upper specification limit? Below the lower specification limit?

$$2\mu_{clearance} = \mu_A - \mu_B = 1.79 - 1.406 = 0.384$$

$$\mu_{clearance} = 0.192$$

$$\sigma^2_{clearance} = \sigma^2_A + \sigma^2_B = (0.0189)^2 + (0.0220)^2 = 0.0008412$$

$$\sigma_{clearance} = 0.029$$

$$z_u = \frac{0.5 - 0.384}{0.029} = 4$$

$\Phi(4) = 0.000032 \Rightarrow$ 0.0032% out of spec on high side

$$z_l = \frac{0.3 - 0.384}{0.029} = -2.9$$

$\Phi(-2.9) = 0.0019 \Rightarrow$ 0.19% out of spec on low side

Total out of spec = 1897 parts per million

d. What assumptions did you make in answering part c?

We assumed random mating and normal distributions. We also assumed that Part A would be centered in Part B so that the clearance on each side is exactly one-half the total clearance.

e. Assuming the process for machining Part A can be re-centered to the target dimension of 1.8, estimate the proportion of the Part A distribution that would be out of specification on the upper and lower sides respectively.

$$z_u = \frac{1.85 - 1.8}{0.0189} = 2.65$$

$\Phi(2.65) = 0.004 \Rightarrow$ 0.4% out of spec on high side

$$z_l = \frac{1.75 - 1.8}{0.0189} = -2.65$$

$\Phi(-2.65) = 0.004 \Rightarrow$ 0.4% out of spec on low side

f. If the process for Part A machining can be re-centered to the target dimension of 1.8, what proportion of the clearance distribution will lie outside the specification limits on the high and low sides respectively?

$$2\mu_{clearance} = \mu_A - \mu_B = 1.8 - 1.406 = 0.394$$
$$\mu_{clearance} = 0.197$$
$$\sigma^2_{clearance} = \sigma^2_A + \sigma^2_B = (0.0189)^2 + (0.0220)^2 = 0.0008412$$
$$\sigma_{clearance} = 0.029$$
$$z_u = \frac{0.5 - 0.394}{0.029} = 3.66$$
$$\Phi(3.66) = 0.000126 \Rightarrow 0.013\% \text{ out of spec on high side}$$
$$z_l = \frac{0.3 - 0.394}{0.029} = -3.24$$
$$\Phi(-3.24) = 0.000597 \Rightarrow 0.06\% \text{ out of spec on low side}$$

Total out of spec = 724 parts per million

g. If you assume that six standard deviations covers most of the distribution, can you suggest a tighter specification range for the clearance specifications?

$$\sigma_{2\,clearance} = 0.029$$
$$\sigma_{1\,clearance} = \frac{0.029}{2} = 0.0145$$
$$3\sigma_{1\,clearance} = 0.0435$$
$$\text{Revised Specs: } 0.2 \pm 0.04$$

Problem 4-7:

The management of Greenfield Tire and Rubber have asked you to review the gum ply and wire reinforce thickness at one of its tire manufacturing facilities. The re-work shop is receiving more than normal jobs that were not meeting the CTA (Critical to Assembly) specification of $0.25\,in. \pm 0.1\,in.$. Meeting these specifications on each assembly is important so that parts do not exceed the limitations of the curing mold. The assembly consists of two layers of material: a gum ply layer and a wire reinforce layer. You have been provided with production data for the gum ply and wire reinforce processes respectively. This data is shown in the following two tables.

Sample Number	Gum Ply Layer Thickness (in)			
	1	2	3	4
1	0.1700	0.1087	0.0961	0.0856
2	0.1888	0.1362	0.2005	0.1371
3	0.1559	0.1320	0.1465	0.1610
4	0.1149	0.1566	0.1381	0.1219
5	0.1289	0.0913	0.1586	0.0903
6	0.1768	0.1150	0.1615	0.1278
7	0.1678	0.1357	0.1942	0.0928
8	0.1927	0.0879	0.1197	0.1379
9	0.1130	0.1590	0.1527	0.1363
10	0.1221	0.1814	0.1434	0.0931
11	0.1621	0.1392	0.0877	0.1392
12	0.1248	0.1322	0.1294	0.1434
13	0.1586	0.1777	0.1601	0.1533
14	0.1617	0.1146	0.1659	0.1385
15	0.1668	0.1311	0.1612	0.1847
16	0.1857	0.1360	0.1416	0.1249
17	0.1216	0.1292	0.1060	0.1207
18	0.1171	0.1406	0.1481	0.1827
19	0.1164	0.1064	0.1283	0.1832
20	0.1366	0.1189	0.1427	0.1566
21	0.1980	0.1784	0.1656	0.1574
22	0.1090	0.1083	0.1340	0.0707
23	0.1291	0.1076	0.1424	0.1833
24	0.1248	0.1285	0.1329	0.1407
25	0.0932	0.1474	0.1659	0.1623
26	0.1485	0.1483	0.1159	0.1278
27	0.1261	0.1458	0.0956	0.1718
28	0.1801	0.1698	0.1403	0.1184
29	0.1628	0.1056	0.1511	0.1421
30	0.1543	0.0906	0.1405	0.1685

Sample Number	Wire Reinforce Layer Thickness (in)			
	1	2	3	4
1	0.1118	0.0687	0.0878	0.0776
2	0.1045	0.0580	0.0682	0.1094
3	0.0889	0.0875	0.0950	0.1086
4	0.0700	0.1089	0.0898	0.0727
5	0.0981	0.0482	0.1004	0.0844
6	0.0586	0.1220	0.0923	0.0783
7	0.0949	0.0795	0.1074	0.0855
8	0.0920	0.0886	0.0944	0.0849
9	0.1114	0.1373	0.0903	0.0536
10	0.0800	0.1029	0.1339	0.0916
11	0.0990	0.0877	0.1195	0.0820
12	0.1619	0.0765	0.0886	0.1075
13	0.0834	0.1174	0.0969	0.1387
14	0.1154	0.0706	0.1177	0.1110
15	0.0911	0.1346	0.0743	0.0924
16	0.0780	0.1176	0.0864	0.1594
17	0.0858	0.1059	0.0536	0.0867
18	0.1000	0.1225	0.0914	0.0811
19	0.0930	0.1095	0.1014	0.1142
20	0.0977	0.1078	0.0658	0.0695
21	0.1100	0.1172	0.1245	0.1081
22	0.1092	0.0938	0.1025	0.0759
23	0.1197	0.1058	0.0774	0.0944
24	0.0637	0.0819	0.1293	0.1082
25	0.1085	0.1343	0.1181	0.0974
26	0.1139	0.1169	0.0704	0.0936
27	0.0927	0.0919	0.1012	0.1282
28	0.1145	0.1144	0.0984	0.1164
29	0.1237	0.1256	0.1216	0.1130
30	0.1173	0.1128	0.1003	0.1306

a. Use these 120 points of raw data provided for each of the components to estimate the parameters (μ and σ) of the distribution of the final thicknesses of individual gum ply wire reinforce assemblies. We shall assume that the processes are stable and repeatable.

$$\mu_{gum\ ply} \cong \bar{x}_{gum\ ply} = 0.1399$$
$$\sigma_{gum\ ply} \cong s_{gum\ ply} = 0.0281$$
$$\mu_{wire\ reinforce} \cong \bar{x}_{wire\ reinforce} = 0.0989$$
$$\sigma_{wire\ reinforce} \cong s_{wire\ reinforce} = 0.021237$$

b. Using the solution you obtained in part (a) estimate the percentage of assemblies that will be outside the specification limits. How many parts per million is this?

$$\mu_{assembly} = \mu_{gum\ ply} + \mu_{wire\ reinforce} = 0.1399 + 0.0989 = 0.2388$$
$$\sigma^2_{assembly} = \sigma^2_{gum\ ply} + \sigma^2_{wire\ reinforce} = (0.0281)^2 + (0.021237)^2 = 0.001239$$
$$\sigma_{assembly} = 0.0352$$
$$z_u = \frac{0.35 - 0.2388}{0.0352} = 3.16$$
$$\Phi(3.16) = 0.000788846 \Rightarrow 0.08\% \Rightarrow 789PPM \text{ out of spec high side}$$
$$z_l = \frac{0.15 - 0.2388}{0.0352} = -2.52$$
$$\Phi(-2.52) = 0.00586774 \Rightarrow 0.59\% \Rightarrow 5868PPM \text{ out of spec low side}$$

c. What would you recommend that the management of Greenfield Tire and Rubber do in order to get the gum ply wire reinforce assembly thickness closer to the nominal specification?

The average assembly thickness needs to increase from 0.2388 to the nominal of 0.25. This requires increasing the average of gum ply or of wire reinforce or both. One of these may be easier (or cheaper) to increase than the other.

d. If management is successful in achieving the target specification, what percentage can be expected to be outside specifications assuming that the process variances for each component remain unchanged? How many parts per million is this?

$$z_u = \frac{0.35 - 0.25}{0.0352} = 2.84$$
$$\Phi(2.84) = 0.0023 \Rightarrow 0.23\% \Rightarrow 2256PPM \text{ out of spec high side}$$
$$z_l = \frac{0.15 - 0.25}{0.0352} = -2.84$$
$$\Phi(-2.84) = 0.0023 \Rightarrow 0.23\% \Rightarrow 2256PPM \text{ out of spec low side}$$

e. Assuming that both components are on target, how much would the variance of the both components have to be reduced to in order to achieve no more than 3.4 parts per million outside either specification limit? Assume that the variances of each component will be in the same proportion of the total after the change as before.

Problem 4-8:
SunTech Co. is developing a new window film that will prevent windows from shattering upon impact. The specifications on the film thickness are 370 ± 10 μm (micrometers). The film is made up of three layers: a dyed polyester film, metallic lining, and a scratch resistant coating. Data collected from the production of each layer component are presented in the table below. The specifications for each component are as follows (all measurements shown are in μm):

Polyester film	100 ± 5
Metallic lining	120 ± 2
Scratch-resistant coating	150 ± 3

Polyester Layer

Sample		*Observation*			
	1	***2***	***3***	***4***	***5***
1	107.1397	99.2086	100.9042	100.0536	102.4504
2	100.8674	102.3427	100.6385	96.3919	100.1238
3	100.3446	100.3614	102.1023	101.2086	101.2238
4	103.2022	98.9172	104.1252	100.0115	98.3616
5	104.7148	100.7343	101.6746	100.3884	104.4914
6	100.8449	103.0214	102.8825	103.3160	102.7463
7	99.1435	100.3274	100.6272	98.9970	101.8641
8	98.8761	99.3938	99.2531	101.7511	99.3864
9	102.7593	100.6944	97.4749	98.8227	104.2506
10	96.3279	100.3979	101.6386	102.2754	100.7074

Metallic Lining

Sample		*Observation*			
	1	***2***	***3***	***4***	***5***
1	118.9965	119.4768	120.1195	121.3607	119.5365
2	119.9275	118.5908	119.0238	120.1219	119.7238
3	121.0552	120.7206	120.5632	120.0192	118.4176
4	120.4201	121.724	118.9609	120.8402	119.2126
5	120.0643	119.5225	120.0839	119.8735	119.9827
6	120.4571	119.2172	119.1524	119.5827	120.6158
7	118.7643	118.5731	119.9608	118.6721	118.0054
8	119.5879	120.8373	121.3822	119.2283	119.0834
9	120.6605	121.2018	118.9951	120.5087	118.8764
10	119.3968	120.8473	120.6957	120.9016	118.3809

Scratch Resistance Coating					
Sample			***Observation***		
	1	***2***	***3***	***4***	***5***
1	147.4471	150.0942	150.9554	150.8616	151.3109
2	153.342	154.1938	149.4951	150.4375	150.8502
3	149.8125	151.6689	149.6252	151.7198	149.5837
4	152.2016	150.9156	150.873	152.1419	149.4748
5	149.2191	149.002	151.3166	148.825	150.9926
6	150.5601	150.2813	150.0309	151.1049	150.8316
7	150.5922	151.0496	148.2893	151.0391	148.8795
8	151.8168	152.6681	148.701	149.4111	151.992
9	150.4225	151.3513	147.2515	148.5842	148.5399
10	151.0835	149.8955	153.0184	150.0018	147.9945

a. Using the 50 data points provided for each component, estimate the mean, variance, and standard deviation for each component and also for the final assembled film thicknesses.

$$\mu_{polyester} \cong \overline{X} = 100.9952$$
$$\sigma_{polyester} \cong s = 2.105399$$
$$\sigma^2_{polyester} = 4.4327$$
$$\mu_{metallic} \cong \overline{X} = 119.8385$$
$$\sigma_{metallic} \cong s = 0.907839$$
$$\sigma^2_{metallic} = 0.8242$$
$$\mu_{scratch\ resistance} \cong \overline{X} = 150.435$$
$$\sigma_{scratch\ resistance} \cong s = 1.477225$$
$$\sigma^2_{scratch\ resistance} = 2.1822$$
$$\mu_{assembly} = \mu_{polyester} + \mu_{metallic} + \mu_{scratch\ resistance} = 100.9952 + 119.8385 + 150.435 = 371.2687$$
$$\sigma^2_{assembly} = \sigma^2_{polyester} + \sigma^2_{metallic} + \sigma^2_{scratch\ resistance} = 4.4327 + 0.8242 + 2.1822 = 7.4391$$
$$\sigma_{assembly} = 2.7275$$

b. For each component calculate the estimated percentage of the relevant production output that will be outside the stipulated specification limits.

Polyester:

$$z_u = \frac{105-100.9952}{2.105399} = 1.90$$

$\Phi(1.90) = 0.0287 \Rightarrow$ 2.87% out of spec high side

$$z_l = \frac{95-100.9952}{2.105399} = -2.85$$

$\Phi(-2.85) = 0.0022 \Rightarrow$ 0.22% out of spec low side

Metallic

$$z_u = \frac{122-119.8385}{0.907839} = 2.38$$

$\Phi(2.38) = 0.0087 \Rightarrow$ 0.87% out of spec high side

$$z_l = \frac{118-119.8385}{0.907839} = -2.03$$

$\Phi(-2.03) = 0.0212 \Rightarrow$ 2.12% out of spec low side

Scratch Resistance

$$z_u = \frac{153-150.435}{1.477225} = 1.74$$

$\Phi(1.74) = 0.0409 \Rightarrow$ 4.09% out of spec high side

$$z_l = \frac{147-150.435}{1.477225} = -2.33$$

$\Phi(-2.33) = 0.0099 \Rightarrow$ 0.99% out of spec low side

c. Estimate the percentage of the assembled films that will be outside the stipulated specification limits.

$$z_u = \frac{380-371.2687}{2.7275} = 3.20$$

$\Phi(3.20) = 0.000687 \Rightarrow$ 0.07% out of spec high side

$$z_l = \frac{360-371.2687}{2.7275} = -4.13$$

$\Phi(-4.13) = 0.000018 \Rightarrow$ 0.002% out of spec low side

d. Assuming that the production distributions for each of the three components can be centered on the relevant target specifications, recommend a set of revised assembly specifications that will ensure that no more than 1% of the films will be too thick and no more than 1% of the films will be too thin.

$$z_u = \frac{380 - 370}{\sigma_{assembly}} = 2.33$$

$$\sigma_{assembly} = \frac{10}{2.33} = 4.292$$

$$3\sigma_{assembly} = 12.88$$

$$\text{Revised Specs:}$$

$$370\mu m \pm 13\mu m$$

e. Assuming that the natural process spread (i.e., 6σ) is exactly equal to the allowed tolerance (i.e., Upper Spec Limit - Lower Spec Limit) for each of the three components, how would your answer to part c change?