Avoiding Design Blunders

Course Content

I. Three Questions

A few months after Galloping Gertie--the Tacoma Narrows Bridge -twisted and undulated itself to destruction in 1940, civil engineering Prof. J. K. Finch, of Columbia University, by-lined an article in ENR titled "Wind Failures of Suspension Bridges or Evolution and Decay of the Stiffening Truss." He recounted numerous instances of aerodynamic instability--some ending in collapse of the structures--dating back to the earliest years of modern suspension bridges.

The Tacoma Narrows Bridge **Source: iCivilEngineer**

In 1955 Col. Edwin L. Coe, US Army, Corps of Engineers, Retired, chose to end his long career by teaching at the University of Illinois. Col. Coe had built bridges, roads and airfields for Gen. Douglas Mac Arthur during his Pacific island hopping campaign against the Japanese in the mid to late 1940s. Col. Coe taught a course called " Engineering Ethics". All freshman engineering students were required to attend; electrical engineers, chemical, mechanical, civil, ……….all.

Had I had the temerity then to ask such questions, which I didn't, they might have been these:

" How should we proceed with the design of this project? Where shall we start? How can we be sure not to blunder somewhere along the way?"

Col. Coe would not have answered me anyway. He would have challenged me, as he did all students, with these three questions in return:

" Why do this at all?"

"How many ways are there to do this?"

"What's the best way to do this?"

Thank you Col. Coe. These questions remain the best and most important we can ask about any engineering task.

They represent too, three of the ways for avoiding blunders, especially in the early stages of the design process. By continually asking these questions of ourselves at each step along the way we can remain focused on our goals. They, and not the innumerable minutiae of design, are our best guide. We'll return to these ideas at the end of this course.

II. Needless Repetition

Overpass Collapse Shuts down Quebec Highway

Date: June 18, 2000

Description:

A huge concrete beam fell on the vehicle as it was passing under the viaduct.

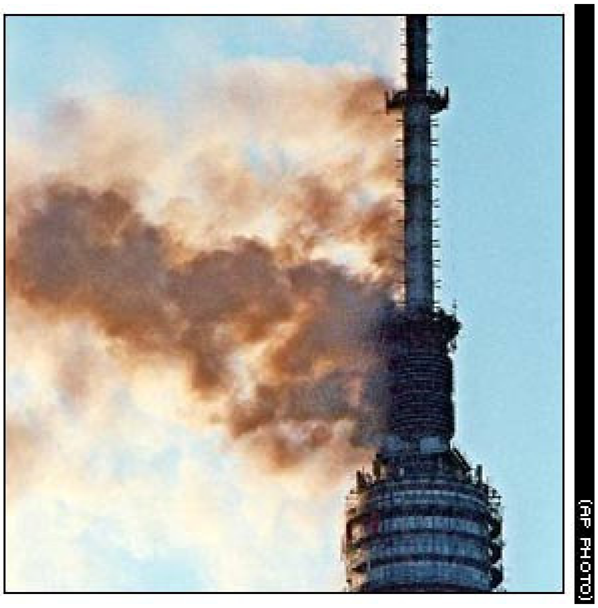
Fallen Concrete Being Removed in Quebec **Source: iCivilEngineer**

If you want to guarantee conflicts between plans and specifications, or between different sheets of the plans, then, by all means, repeat dimensions, notes details and other elements!

At first, we may think that repeating things will help to clarify them and emphasize their importance. But there is a trap here which is all too easy to fall into. Consider this common scenario. You are preparing plans for a retaining wall which is to be 10 feet in height. There are several sheets to the plan set and the wall appears on three of them. Each time the wall is shown you dimension and label it using the 10-foot design height. Late in the design process, when deadlines loom and conditions are at their most hectic, you discover that the wall needs to be 12 feet high. So you hastily redesign and change the plans accordingly. But you overlook one of the three sheets! Now you have created a conflict. Sheet 5 does not agree with sheet 7. Your contractor doesn't know which is correct and you now have the additional duty to correct this error and possibly issue a change order for increased costs. As you know, these are never a welcome sight to your client or employer.

The best rule here is to say it once and say it correctly. Don't repeat things if you don't have to. Changes always occur and small oversights like this can and will happen.

III. Show and Don't Tell



Moscow Television Tower Fire

Source: iCiviEngineer

Moscow's Giant TV Tower Collapse

Date: August 28, 2000

Description:

Completed in 1967, the Europe's Telecommunications tower's exposed prestressing cables inside are vulnerable to blaze.

Links:

CNN: Fire rages in Moscow's giant TV tower

Official Website: Ostankino TV tower

A set of construction plans may be thought of as a set of graphical instructions to the builder. Specifications, and notes on the plans, are the verbal instructions. When we wish to describe some physical object or condition the plans are the logical place to convey that information. They are also the most efficient means for doing so. Things like size, shape, dimensions, tolerances, spatial relationships among components, etc. are best "shown" rather than being described in words. To understand this simply imagine trying to describe the Moscow Television Tower using only words; no pictures allowed. Your description would run on for thousands of pages and would probably end up being unintelligible to everyone, including yourself.

Also, recognize that the plans are the principle means you have for communicating to the builder, and others, what it is you intend to create. Specifications produced for a project tend to be voluminous and are seldom read or referred to once construction begins. But the plans are consulted daily by everyone involved in the construction process.

IV. Manual Overrides

As computers increasingly make possible the automatic operation of things we are very tempted to automate every process. Resist this temptation.

Apollo 11 Crew Source: NASA

The first human journey to the surface of the Moon began at Pad A, Launch Complex 39, Kennedy Space Center, Florida with the liftoff of Apollo 11 on a Saturn V booster at 9:32 a.m. EDT (13:32 UT) on a clear sunny Wednesday, 16 July 1969.
(NASA photo ID S69-39525)

The picture shows the crew of Apollo 11: Commander Neil A. Armstrong, 38, a civilian who'd flown previously on Gemini 8, Command Module Pilot Michael Collins, 38, a USAF Lt. Colonel who'd flown Gemini 10, Lunar Module Pilot Edwin E. Aldrin, Jr., 39, a USAF Colonel who'd flown Gemini 12. Photograph taken May 1, 1969.
(NASA photo ID S69-31739)

In his book, ***The Right Stuff***, Tom Wolfe describes the running battle between the original Apollo 11 astronauts and the NASA scientists and engineers. The astronauts, being all fighter and test pilots, want to fly the spacecraft. They are used to being "pilot in command" and to making split second decisions under difficult circumstances. The non-pilots at NASA wanted none of this cowboy mentality. They wanted the crew to go along for the ride and not touch the controls or operate any of the onboard systems. The crew members view this as being asked to be what they called "Spam in a can" and constantly lobby the designers to install manual systems which can bypass the automatic flight and other controls. As it turns out, the pilots are right. Here is a short excerpt from a review of the book:

" Tom Wolfe began The Right Stuff at a time when it was unfashionable to contemplate American heroism. Nixon had left the White House in disgrace, the nation was reeling from the catastrophe of Vietnam, and in 1979 -- the year the book appeared -- Americans were being held hostage by Iranian militants. Yet it was exactly the anachronistic courage of his subjects that captivated Wolfe. In his foreword, he notes that as late as 1970, almost one in four career Navy pilots died in accidents. "The Right Stuff," he explains, "became a story of why men were willing--willing?--delighted!--to take on such odds in this, an era literary people had long since characterized as the age of the anti-hero."

"Wolfe's roots in New Journalism were intertwined with the nonfiction novel that Truman Capote had pioneered with In Cold Blood. As Capote did, Wolfe tells his story from a limited omniscient perspective, dropping into the lives of his "characters" as each in turn becomes a major player in the space program. After an opening chapter on the terror of being a test pilot's wife, the story cuts back to the late 1940s, when Americans were first attempting to break the sound barrier.

Test pilots, we discover, are people who live fast lives with dangerous machines, not all of them airborne. Chuck Yeager was certainly among the fastest, and his determination to push through Mach 1--a feat that some had predicted would cause the destruction of any aircraft--makes him the book's guiding spirit.

"Yet soon the focus shifts to the seven initial astronauts. Wolfe traces Alan Shepard's suborbital flight and Gus Grissom's embarrassing panic on the high seas (making the controversial claim that Grissom flooded his Liberty capsule by blowing the escape hatch too soon). The author also produces an admiring portrait of John Glenn's apple-pie heroism and selfless dedication. By the time Wolfe concludes with a return to Yeager and his late-career exploits, the narrative's epic proportions and literary merits are secure…………….

"The men had it. Yeager. Conrad. Grissom. Glenn. Heroes...the first Americans in space...battling the Russians for control of the heavens...putting their lives on the line. The women had it. While Mr. Wonderful was aloft, it tore your heart out that the Hero's Wife, down on the ground, had to perform with the whole world watching...the TV Press Conference: "What's in your heart? Do you feel with him while he's in orbit?"

In the end, the NASA scientists and engineers learned that always providing a way around the automatic systems was the best insurance against failure. And the astronauts learned too. We can all learn from their experience. People will use, and possibly misuse our designs. We need to offer them an escape hatch when that happens.

V. Redundancy = Reliability

Failed Dam in Syria **Source: AP Wirephoto**

A Dam in Northern Syria Collapses

Date: June 4, 2002

Description:

A dam in northern Syria collapsed, killing at least two people.

Links:

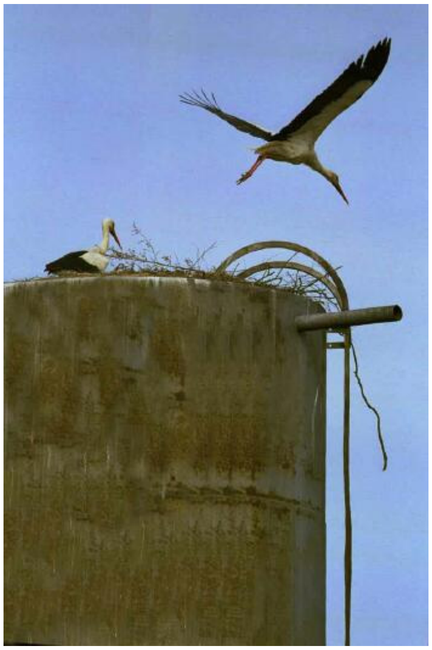
Yahoo!: Dam Collapses in Northern Syria

For those systems you design which need to be highly reliable, the simplest way to ensure that is through intentional repetition. A water pump station, for example will almost always contain at least two pumps; each capable of delivering the full design capacity of the station. These pumps are alternated during pumping cycles to even up wear. Should one pump fail, the system will continue to operate for a time to allow repair or replacement of the failed pumping unit.

Standby power generation is also a feature of such stations, and for the same reasons of reliability.

This kind of redundancy is practiced in many areas of design.

VI. Reality Checks



On April 25th -26th, 1986 the World's worst nuclear power accident occurred at Chernobyl in the former USSR (now Ukraine). The Chernobyl nuclear power plant located 80 miles north of Kiev had 4 reactors and whilst testing reactor number 4 numerous safety procedures were disregarded. At 1:23am the chain reaction in the reactor became out of control creating explosions and a fireball which blew off the reactor's heavy steel and concrete lid.
The Chernobyl accident killed more than 30 people immediately, and as a result of the high radiation levels in the surrounding 20-mile radius, 135,00 people had to be evacuated.

Cranes nesting at the destroyed Chernobyl Nuclear Plant **Source:**

At the beginning of the design we can ask ourselves Col. Coe's three questions, recognizing that question 1 is what an attorney would call a "threshold question". If you can't satisfactorily answer it, there is no need to go on to the other two questions or the project itself.

Our next step might be to conceive some preliminary plan for the project and sketch it out on paper. This will not be very detailed and we will have many questions at this stage. This is as it should be.

Reality check number one is a site visit. You will want to do this early so that you can begin to refine your design ideas and assumptions based on first hand information. Surveys, maps and photos are great but cannot compare to being on the ground, yourself. You will learn more in half an hour on the site than you can possibly imagine in months at your desk. For Civil projects, such a visit is mandatory.

As the design moves along we must continually check our conclusions and decisions against reality. For example, let's say we've sized a culvert for a road crossing and arrived at a size of 12-inches in diameter. From a site visit we know that the stream this culvert will carry is 8 feet wide by 4 feet deep. Red Flag! The pipe is probably undersized for any really severe storm condition.

At the end of the design process we have an opportunity to ask again the three questions presented in Section 1 above. Why did we do what we did? Did we consider all the ways we might have done it? Why did we choose the final design solution?

VII. Changes: When? Why? How?

The streets in the city of Bhopal are littered with the carcasses of buffaloes, cows, dogs, and birds.

The governor of the state has appealed for calm." (December 3, 1984)

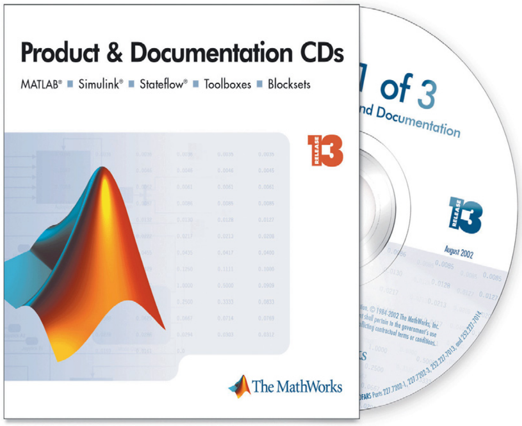
In the early morning hours of December 3, 1984, one of the worst industrial disasters in history began when a pesticide plant located in the densely populated region of Bhopal in central India leaked a highly toxic cloud of methyl isocyanate into the air. Of the estimated one million people living in Bhopal at the time, 2,000 were killed immediately, at least 600,000 were injured, and at least 6,000 have died since. The leak was caused by a series of mechanical and human errors in the pesticide-producing plant, operated by the Union Carbide Corporation, a U.S.-based multinational.

Sign at Bhopal, India Union Carbide Plant **Source: The History Channel**

Changes are expensive and the later in the design process they occur, the more expensive they are. On large projects, and even some smaller ones it is good practice to develop a preliminary design addressing all the major issues. Then, you may want to formalize that plan by writing a Pre-Design Memorandum. The purpose of the PD Memo is to inform everyone involved in the design, including the Owner, of the basic design features and gain their concurrence. The Owner will be the toughest person to get on board. After that, the design must not be changed without the agreement of everybody that the change is necessary and beneficial to the finished product.

A Pre-Design Memo is especially important in "team" design. It keeps all members of the team informed and focused on their part of the design without losing sight of the overall goals.

VII. Software Dangers



Every computer program forces you to think in ways different than you are used to. Each will also have a learning curve which may be steep and time consuming. Consider these factors when you choose software and preview it if possible.

MathLab **Source: MatLab.com**

Even if chip makers reduce the microprocessor to the molecular level, they cannot make it think. Computers can, however, multiply your mistakes at near light speed.

When you acquire some new software it is suggested you test it out using a small data set or simple problem to which you already know the answer. If the software vendor supplies samples use those too but independently check the results by other means.

As you try out the new program, try to make a few deliberate mistakes and see how well the program handles "error trapping". Does it warn you and give you another chance to correct your error or does it simply dump you out of the program and make you start all over again?

Be wary of those "automatic save" features which are supposed to help you. If you, like I, often clone solutions from one project to another, these auto-saves can cause you many headaches and overwrite your original file all too easily when that is not what you wanted to do.

IX. Pilot Studies - Small Steps

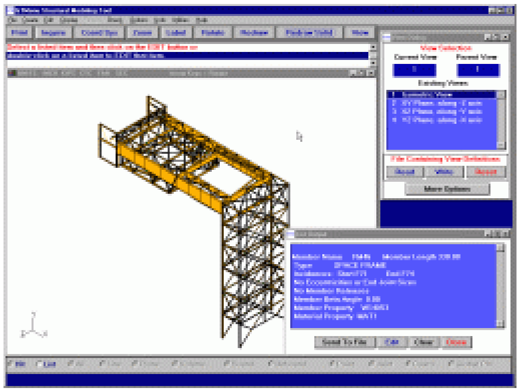
Leaning Tower of Pisa Source: Gary Fuerstein

The Tower of Pisa is the bell tower of the Cathedral. Its construction began in August of 1173 and continued (with two long interruptions) for about two hundred years, in full fidelity to the original project, whose architect is still uncertain. In the past it was widely believed that the inclination of the Tower was part of the project ever since its beginning, but now we know that it is not so. The Tower was designed to be "vertical" (and even if it did not lean it would still be one of the most remarkable bell towers in Europe), and started to incline during its construction.

A small mistake is tolerable and may avoid the big blunder that will end your career. For any new, untried system a small-scale pilot study should be devised. This may not always be possible. In some fields, such as water treatment, such studies are routine but some processes are difficult to scale up.

Computer modeling has become very important in this field. Entire river systems can be modeled in great detail using software, and a little experience. Both water quality and quantity can be examined in this way and serious, unwanted consequences avoided.

X. Peer Review



Structural Frame Model **Source: STRUDL**

It goes by many names and garbs itself formally and informally but whatever its guise; Peer Review is your friend. In some organizations peer review is formalized and renamed. "Value Engineering" is one example of this. Whatever its name, take advantage of thoughtful, competent criticism by your fellow designers. And, be prepared to return the favor.

But why do we need this extra layer of review? We check our own work and are very careful, aren't we? Yes, but, in truth you cannot really check your own work with 100 percent accuracy. Moreover, you deprive yourself of the insight and experience of others when you skip the peer review process. They may see things your eye simply skips past and they may know from their experience when you've made an oversight or committed a gross error. Your colleagues can, and most will, help you. It is the cheapest insurance on the market.

XI. Reinventing Wheels

At approximately 7:15 p.m.on the stormy night of 28 December 1879, the central navigation spans of the Tay bridge collapsed into the Firth of Tay at Dundee, taking with them a train, 6 carriages and 75 souls to their fate. At the time, a gale estimated at force 10 to 11 was blowing down the Tay estuary at right angles to the bridge. The collapse of the bridge, only opened 19 months and passed safe by the Board of Trade, sent shock waves through the Victorian engineering profession and general public. The disaster is one of the most famous to date it is still the worst structural engineering failure in the British Isles

The Tay Bridge **Source: Tom Martin's Tay Bridge Disaster Web Page**

You may think of this as what Benny Hill used to call a"trilogy in four parts". To Col. Coe's three questions listed in Section 1, let's add a fourth:

"Has this wheel been invented?

Most projects are not unique in all respects. When faced with a new design assignment, you'll find it very useful to look around your own, and other, organizations to see if you can find similar projects. If there are such parallels, use them as models of both what you want to accomplish in your design and what errors you want to avoid. If these other projects have been built and put into service, see if you can visit them and talk to the people who own and operate them. They'll tell you what they like and don't like and that kind of information can be invaluable.

You don't have to reinvent the wheel on every job but you do have an opportunity to make it rounder.

XI. Command Type Sentences

Building Collapsed in San Antonio

Date: Decmber 4, 2002

Description:

A five-story building collapsed in downtown San Antonio, 3 people injured.

Links: New8Austin: Building collapse in San Antonio

Tyler Morning Telegraph: Tow Workers Injured in Building collapse

My San Antonio: Workers clear last of debris; no more victims found

My San Antonio: Storied structure wore many faces

My San Antonio: Old wall was bolted to new steel cage

Specifications, notes on the plans and other directions to the builder are unavoidable. They can best be framed as commands, a few examples of which are shown below. The advantage of this is not only brevity, but also clarity. Words can be very tricky which is, one suspects, why attorneys love them and engineers hate them.

Here are some examples of command sentences:

Styles

Command Sentences

The Construction Specifications Institute (CSI) guide specifications use command type sentences extensively. All directives are assumed to be addressed to the Contractor. In a few instances it may be necessary to address other members of the construction team but these are exceptions. Note that no sentence begins with the tedious "The Contractor shall…" or " Except as otherwise directed…" .

Verbs

The key to this style of writing is to make most sentences begin with a verb. Verbs are the action words of the English language and, when used, automatically employ the active voice rather than the passive voice. These kinds of sentences tend to be shorter, clearer and more direct.

It would be difficult indeed to misunderstand a sentence such as, "Stake and flag locations of known utilities."

Useful phrases

Clearly, the CSI format and style lends itself well to brevity. Many of the sections consist of only phrases. Meaning can be conveyed without the need to write complete sentences. Again, this is the result of understanding that all sections are meant to be directives to the contractor, eliminating the need to repeatedly refer to him or her.

Other ways the CSI style helps is by defining several repetitious phrases up front. Examples include:

> "as shown" which always means as shown on the plans, drawings, shop drawings or other graphical elements of the contract documents.
>
> "as directed" always means as directed or ordered by the Architect or Engineer.

"as required" always means as required by some other part of the contract documents which may include reference specifications or manufacturer's recommended practice or permit conditions.

Confusing and unneccessary phrases

Specifications all too often contain confusing phrases easily misunderstood or simply wasteful of everyone's time. An example might be the phrase, "unless otherwise shown or directed".
After reading this phrase, the typical bidder will immediately ask himself or herself what it means. Does it mean there is some detail of the plans which is different than all the other similar details? Does it mean that the architect may arbitrarily require some construction different from that shown or specified? Does the bidder have to hunt through all the documents looking for such exceptions to the general rules? If the bidder doesn't find the exception because there are no such exceptions, everyone's time is wasted with unnecessary questions.

Phrases which create doubt in the mind of the bidder/contractor will always cause confusion and usually lead to higher costs or requests for change orders later. In extreme cases they can lead to lawsuits.

Prescriptive vs. Objective Specifications

Both kinds of specifications may be used on any particular project, although objective specifications should be favored.

Prescriptive example

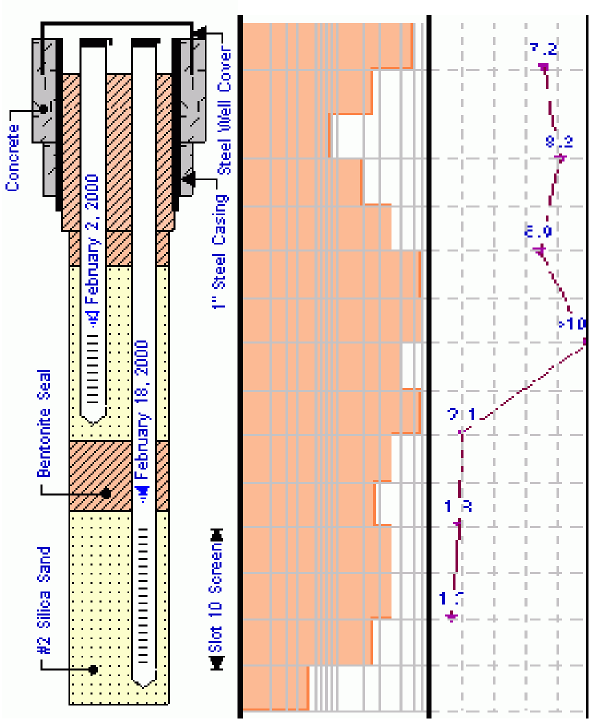
Specifications which require not only that some work be done, but which also detail the means for accomplishing that work are prescriptive. Such specifications are appropriate in some cases, however. For example, the specifications for pressure testing a water main are usually written this way. The water supplier, in order to be consistent on all projects, will usually provide this test procedure. The procedure will ordinarily have been developed over many years and be pretty close to a standard.

The great danger of prescriptive specifications lies in the fact that they can create a liability for the designer. When you tell the builder not only what you want done but how he is to do it you are assuming responsibility for the final result. Be very careful about this.

Objective example

Generally it is a better idea to give the contractor as much freedom as possible in performing the work. Doing so will almost always result in lower costs and good contractors can be very innovative in devising ways to get the work done. For this reason, it is a good idea to specify the results desired without dictating procedures. Most specification sections can be written this way, and should.

XIII. Including Design Data



Well and Soils Boring Log **Source: GAEA Technologies, Ltd.**

There are those who think it undesirable, even dangerous, to let the builder and others know what information your design is based on and what you intend to accomplish. But information such as soil boring logs, Code criteria, design loads (including wind, seismic or special loads), design flows and organic loadings, pump curves, and the like can be very helpful to the person responsible for making your design a working reality.

This must be done with some caution, of course, since the builder, and others, will rely upon it to some extent and you need to ensure that the information is reliable and accurate. Where it is not, as for example uncertain data such as unverified utility line locations, then you'll need to make that clear and require the builder to field verify such information.

XIV. Conflicts Between Plans and Specifications

Speedway Bridge at North Carolina, USA

Date: May 20, 2000

Description:

A concrete pedestrian walkway spanning a four-lane highway in front of the speedway collapsed, injuring more than 100 people.

Source: iCivilEngineer.com

Even if you've followed the advice, suggested above, to eliminate unnecessary repetition you may still find conflicts between the various elements of a set of contract documents.

To meet this, often specifications are written to pre-determine the order of precedence among the contract documents. Here is a sample of such a specification:

"Precedence

" If there is a conflict between contract documents, the document highest in precedence shall control. The precedence shall be: first, permits from other agencies as may be required by law, second, Special Provisions, third, Plans, fourth ……………………………………. Sixth, reference specifications."

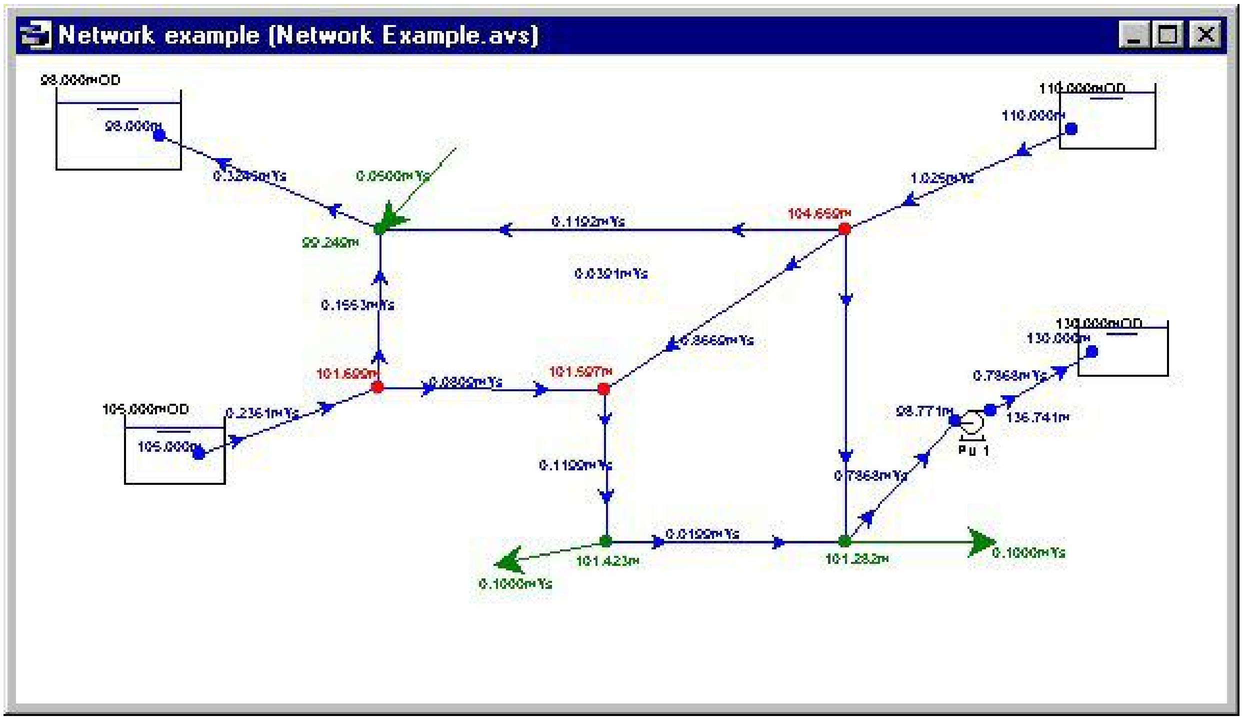
Some specification organizations such as CSI, prefer an alternate approach which emphasizes the intent of the design. This kind of specification can be written similar to the following:

" If a conflict, error, omission, or lack of detailed description is discovered in the contract documents, the Contractor shall immediately notify the Engineer (Architect) and request clarification. The Engineer (Architect) will resolve the conflict and make any corrections or interpretations necessary to fulfill the intent of the plans and specifications. "

This recent trend away from such specific requirements comes about for one simple reason. We do not know, before they are revealed, what problems will arise. Declaring a specific order presumes we know how best to solve a problem, before we know what the problem is!

XV. Schematics and Typical Sections

Even the simplest projects deserve to be thought through with an eye on the ultimate objective, namely; how do we want this thing to work?



Schematic of a Water System **Source: Aquavarra Research, Ltd.**

Schematics should be drawn early in the project and included in any Pre-Design Memo. Once adopted by all they should not change for some trivial reason. Remember, a schematic tells us how things will work; not how they look.

Typical sections are another source of easy blunders. It is very common to use typical details from one project to another to save time and energy. But be careful to make sure the section you use is truly typical for the present project. The best way to do this is to use an actual section from the project you are working on. Select one which represents the most common condition and then label only the parts that are really typical of all or most of the rest of the project.

XVI. Spatial Thinking

The little boy is in the same room
of (sic) the older man.
Still, the boy looks much bigger!

The Ames Room Illusion **Source: http://www.picpal.com/ames.html**

We are taught in elementary drafting courses to think in three dimensions and to draw things to scale. The reasons for this are obvious but often overlooked. One example comes to mind which recurs all too often. A building is designed to house a large piece of equipment but none of the doors is large enough to permit removal of that equipment. After the walls are in place it becomes nearly impossible to remove and replace the equipment at reasonable cost.

We also learn early that we can design things which cannot be built. As the design proceeds it is very important to imagine that you, the designer, will have to build it yourself. This forces you to think through the construction process. What will you do first? What next? What tools or equipment will you need? How big are they and how much room will they require to operate? How heavy are things? Can they be lifted into place in the space and with the equipment available?

XVII. Maintenance Means

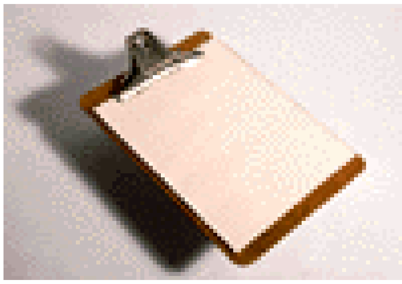
Confluence of Mississippi and Missouri Rivers, August 1993. Extensive floods in the Mississippi River Basin during the spring and summer of 1993 caused $20 billion in damages. (Photograph, Srenco Photography, St. Louis, Mo.)

The engineer who designs a water treatment plant without consulting the people who will operate and maintain it is asking to be lynched at the ribbon cutting ceremony the day the plant opens.

In his book, ***Water Treatment Plant Design***, Robert L. Sanks, PE, PhD suggests that the development of the Operations and Maintenance (O&M) Manual be an integral part of the design process. It should, he tells us, be begun during the design process and proceed along with it. Once constructed, the project must undergo a "breaking in" period which includes training for the operators led by the designer(s) and other qualified people.

During those early stages of operation many design flaws may be detected and corrected. If the maintenance people were involved in the design all along such problems should be minor. If not, some problems will almost certainly be difficult to resolve.

XIX. Check Lists



The lowly list deserves a higher place in our esteem. Despite its simplicity, a list is a powerful tool for organizing thought. It can be added to or subtracted from and morphed into other useful documents. From it one can develop an outline, or a specification, or a work schedule, or a budget or a report.

Robert L. Sanks, for example, developed the following check list for Water Treatment Plant Design. You might easily develop similar lists for the kinds of design problems you work on frequently.

- ***Schematics***
  Flow Diagrams
  Process Instrumentation Diagrams
  Alternate operation, seasonal use, maintenance or equipment breakdown
  Basin volumes, detention times
  Valves/controls numbered and referenced to O&M Manual
  Mechanical, maximum / minimum rates. Hp
  Hydraulic profiles
  Design Criteria

- ***Space***
  Site: allow for future expansion
  Structures: architecture, steel reinforcement, pipes: allow for future expansion
  Sufficient space for connections, valves, vents, drains, headroom
  Operating clearance for handwheels/valve operators
  Working room, especially doors and hatches, for largest removable component
  Access to back of panels and other equipment
  Space for future feeders, mixers, etc.
  Conflicts/hazards e.g. electrical and hydraulics
  Isolation: chlorine, dry chemicals
  Sound and heat insulation
  Stairs and ladders/nearby hoist
  Laboratory: work benches, sinks, safety equipment
  Workshop: tool room, garage
  Lavatory and safety shower

- ***Flexibility***

  Excess hydraulic capacity, oversized piping

Extra feeders/ alternate points of application
Corrosion control
Bypass piping/wiring
Process instrumentation
O&M Manual: describe all modes of operation

- ***Special Considerations***

Freezing: sufficient bury or insulation
Draining and flushing: hydrants and drains
Sludge removal
Ventilation: especially covered basins
Safety: railings, rescue, chlorine, chemical handling
Access: stairs and walkways
Cross connections eliminated

- ***Operation and Maintenance***

Slope floors to drain
Easy housekeeping
Valves and controls located for easy use
Recorders located for easy reading and service
O&M Manual: describe normal, alternative and emergency operations simply

XX. Sometimes Timing is Everything

Furnace Run Iron Aqueduct, on the Ohio & Erie Canal.

The original stone arch culvert that carried the Ohio & Erie Canal over Furnace Run washed out in 1828, less than a year after the opening of the canal in the Cuyahoga Valley. After several episodes of repairing the culvert after washouts, an iron bowstring truss aqueduct replaced the culvert by 1860. Furnace Run kept its reputation for flooding, requiring several reconstructions of the aqueduct to keep the canal open.

Nearly everything designed ends up being a structure of some sort. It must, at a minimum, be strong enough to sustain its own weight. Usually, it must also carry loads imposed upon it during its lifetime. Is there a critical time in the life of a structure, we might ask? The answer varies with the type of structure, of course, but often that critical time is early; even before the structure is completed and put into service.

Consider these three examples.

An underground pipeline is to be built and pressure tested with water. The pipe is laid in a trench and partly backfilled. Some joints and fittings are left exposed so that leakage, if any, may be easily detected. The trench surface is eventually to be paved but that won't be scheduled until after completion of the pressure test. When placed in service, this pipe may be expected to experience internal pressure up to 75 psi.

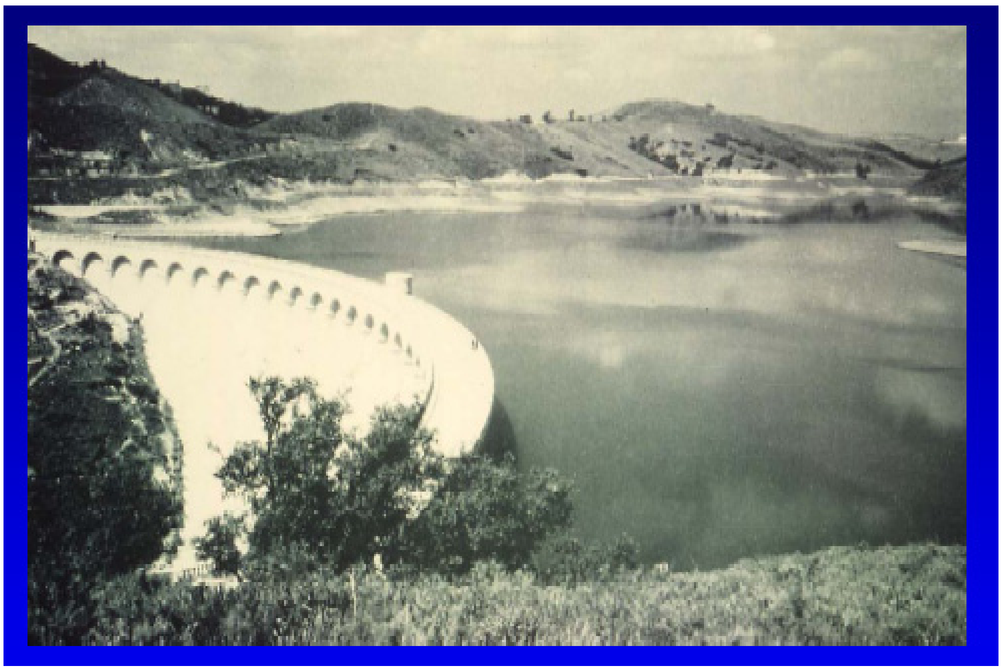
This is a critical time in the life of this pipeline. When it is empty, the trench loads caused by the weight of the soil are large and heavy construction equipment crossing the trench will add live loads to these. When the pressure test is performed, internal pressures will probably be 150 psi or more. Concrete thrust blocks which are not completely cured or not properly installed may move, causing separation at pipe joints, rapid failure and danger to workers, equipment and property.

A through truss bridge is under construction across a windy gorge. The contractor has erected the main trusses supporting them on timber falsework. Lateral bracing is light timber as well so as to allow as much working room as possible for completion of the permanent bracing, decking, and other work to follow.

If this bridge has the misfortune to be hit by an unseasonal windstorm at this critical time in its life the consequences can be complete collapse. The ensuing rework and lawsuits may be costly indeed as each party to the contract seeks to avoid these costs.

In a stream bed, a large, cast in place, box culvert is formed and poured. The stream has been diverted through a small side channel to permit work in the dry. The last pour is for the "roof" of the culvert and is protected by the wooden formwork. A flash flood can now wreak havoc on this uncompleted work. If the flows exceed the capacity of the side channel the stream will revert to its original bed and probably damage, if not wipe out, the new culvert, backfill materials and anything else left in its way.

Very often, the critical time in any structure's life is during construction as the examples seek to illustrate. Consider this, and any other extreme condition your design might encounter.



XXI A Sad Example

William Mulholland

"There it is. Take it."
-- William Mulholland, 1913

"William Mulholland (1855-1935) was born in Ireland, took to sea as young man, and arrived in San Pedro in 1877 where he found work as a ditch tender with the Los Angeles City Water Company. A self-educated engineer with minimal schooling, he went on to become superintendent and chief engineer of the city's water department, a position he held for more than 40 years.

"A natural leader, Mulholland, known affectionately as "The Chief," was entrusted with building a 233-mile aqueduct, the world's longest at the time, to bring water from the Owens River north of Los Angeles to the San Fernando Valley, where developers awaited conversion of dry land into farms and housing tracts. Some called the project "the rape of the Owens Valley," and Owens Valley farmers sometimes violently protested the project. The story, in greatly fictionalized form, became the inspiration for the movie "Chinatown." Dubbed the "Panama Canal of the West," the project required the massing of 3,900 workers and the digging of 164 tunnels, almost 52 miles in all. The first Owens River water flowed into a San Fernando Valley reservoir on Nov. 5, 1913. At the ceremony marking the occasion, the laconic Mulholland uttered what may be the five most famous words in the city's history, "There it is. Take it."

"Fifteen years later, on March 12, 1928, Mulholland's career took a tragic turn when the St. Francis Dam, one of several dams built to increase storage of Owens River water, collapsed, sending 12 billion gallons of water into the Santa Clara Valley, north of Los Angeles. The flood claimed over 400 lives. The Coroner's Jury that investigated the failure of the St. Francis Dam reached three conclusions: 1) that the underlying rock structure was of poor quality and the design of the dam was not suited to the inferior foundation; 2) that there was an error in engineering judgment in determining the character of the foundation of the dam site and in deciding the best type of dam to build there; and 3) that there was an error in regard to fundamental policy related to public safety, in that excessive responsibility was vested in one person and no independent experts were authorized to check on his work. In essence, the Jury found that Mulholland, although not criminally liable for the deaths, did make serious errors. "The Chief" took full responsibility, saying: "If there is an error of human judgment, I am the human." Several months later he retired. His final years were lived in the shadow of the St. Francis Dam collapse.

"Mulholland remains a legendary and controversial figure in Southern California history, the man credited by many with making modern Los Angeles possible. In a gesture of civic gratitude for building the aqueduct, the city named its most scenic highway in his honor. To this day, a trip along Mulholland Drive is a "must" for anyone wishing to grasp the immensity of the metropolis he helped to build."

-- Contributed by Albert Greenstein, 1999

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IXXII Conclusions

For good reason, Architects, Engineers and other designers are licensed in most states and held to a high standard of care in their work. The things we design may be used, and misused, by the public and it is their health and safety which must be protected by the licensing laws. The standard of care is not perfection but something very close to it.

There is a psychology of failure. Our first reaction is usually denial. This can't be happening, we think. Once we're convinced it is that reaction is quickly followed by a search for reasons, excuses, others we can blame this on. It is very often easy to find others but finding them doesn't help our consciences very much and won't deflect all of the blame.

It is hoped that this litany of homilies, admonitions, egregious examples and suggestions will be taken as they are intended. Not as preachments but as colleagial dialogue between design professionals.