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Ins and Outs of Chemical Process Engineering



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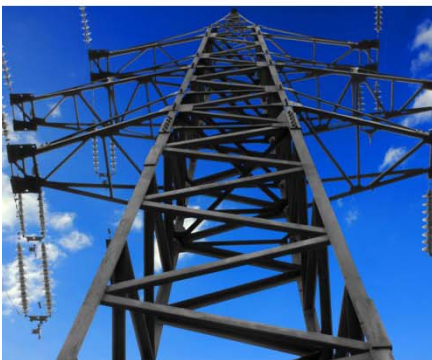
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Professional Development Training Course for Registered Engineers

Ins and Outs of Chemical Process Engineering

Tape 1 – Side 1 (01 track_1.10.25)

This is tape one, side one of a Professional Development Hour Course, titled The Ins and Outs of Chemical Process Engineering.

My name is Ed Hardin. I am a registered professional engineer in the State of North Carolina and my background is fifteen years in a variety of operating plants, manufacturing plastics, commodity and organics and then plant design and construction for 25 years. This time included several periods in operating specialty organic facilities. My work included specifying processes and equipment for and starting a variety of successful production systems. I've also provided process trouble shooting and revamp coordination for plant operations and utility systems.

With this course I want to offer some insight on the review and selection activities that must accompany a process development or revision. These ideas include a variety of real situations that have been part of process reviews where I have been privileged to participate, as well as some general comments from publications. I believe these will be helpful to all engineers as they consider defining a process system but the comments here refer principally to engineers who must decide what needs to be part of the process and what may not need to be included. Some of these situations will seem a bit surreal but they are generally true and personal. I hope to make the humor of some of the conditions a means to make the basic point easier to remember.

There are two principle articles that I reference in this discussion. Copies are provided for your future use; but in addition many of the comments come from my direct experience in new plant development. The articles that I will refer to periodically are first, "You Can Be a Smarter Chemical Engineer" written by Charles E. Carroll of Walnut Creek, California and published in a McGraw Hill *Chemical Engineering Magazine* desk book and short cut manual that they generally provided as a give away with subscriptions that were done in the 60s through the 80s. The second article that I will refer to is one titled, "How to Avoid Common Pitfalls in Making Cost Estimates." This was prepared based on a speech given by a Mr. Buchanan of DuPont at an American Association of Cost Engineers meeting and was published originally in *Chemical Engineering Magazine* in October of 1965.

Also significant as background for our discussion is the concept that for most processing plants the process and instrument diagram is the basis from which the projects builds. I have found that for Europeans in related project activities the equipment arrangement seems to be a base drawing with some attended recognition of process conditions and its affect on the process but generally

related to the arrangement. While I confess I much prefer the P&ID basis I won't say that it is the only way since in some cases I also have used an equipment arrangement as the background for the P&ID due to key equipment retirements. And, in addition, there are a few principles that are considered first. These may change as the process development proceeds but a clear intention at the start in line with these suggestions can help in many of the decisions that need to be made during the system analysis.

The first of these is the process to be continuous or batch? This is often dictated by the required processing or by the fact that initial development was performed in a certain way. It may be appropriate to reconsider that condition as the process scheme is considered for a larger plant or to reconsider at some point in the process as to whether it can be changed from a continuous to a batch or batch to continuous type operation in order to provide certain operating advantages.

A few comments to review in situations that might demonstrate this a bit. It may reduce clean out requirements if a blending or modification process can be continuous. The time of a run is lengthened. The performance of a particular material or a particular blend can be carried out over a longer period of time in a uniform processing system. Certainly at some point if time degradation is of significance that needs to be considered but generally if it is strictly a blending or modification in that way a continuous process tends to be a little bit more advantageous.

Another item may be to reduce the amount of tankage and material sitting and, of course, the pad areas that would be required for that tankage if a pipeline can replace holding, transferring and returning of fluid quantity to the process system. Also, it may be better to risk a fixed quantity of material in a modification operation rather than cause a pluggage that could block total production for the recovery period. So this is one thing that would tend to lean more to the batch type operation. Obviously, these are not simple decisions in some cases. In others there's no decision required. The existing conditions must be maintained.

Moving on into another idea that should provide a good base for analysis and decision is the plant, a big plant or a small plant. These, of course, are relative terms and will bear consideration for your particular industry. As an example, a steel plant may be considered small if its \$200 million and appropriate processing rates. Or an organic specialty facility could be considered big if it's \$4 or \$5 million and dedicated to a high value added product. The defining criteria can sometimes be considered under the question how large a quantity am I willing to put at risk in the process step? This can either be a value quantity or a weight quantity due to the potential for handling results. An example of this might be something that is violently explosive and you don't wish to risk a very large quantity of this in processing because of the potential damages.

Continuing with this idea, another significant concept is the idea of the value of the product or the commodity being produced. Certainly it's the concept such as are the raw materials very expensive. Would that dictate smaller quantities in any process system to reduce the potential for losses; or is the product very expensive so that processing generates significant cash flow and the greater return on the time and effort invested justifies larger quantities to increase the potential return.

Another corollary item is contamination a serious problem? Pharmaceutical products might justify significant handling systems for materials or some materials that will be used for agriculture applications where changes from one product to another might lead to contamination between products. And finally, where later high temperature processing could provide for clean up or correction of materials that might be blended in or other conditions of later processing will influence the degree of clean up that would be required and the quantities of materials being considered for processing.

A short example that I would insert here for consideration is one particular facility in an industry that I worked in where a commodity product was made in very large volumes. The downstream plant receiving this commodity product prepared a list of product improvements that they would like to see with indications that it would make their processing easier and more efficient and more effective. The company manufacturing the commodity product and passing it on looked over this list and developed plans to acquire or to achieve each of the product improvements listed and, of course, generated a cost to achieve these plans and it's affect on the overall product cost. This was reviewed with the user and considered in detail on each one of the items and, of course, as you might expect many of the early requirements or demands turned out to be wishes, which could in many ways more easily be solved in the user's process than in the manufacture's plant.

Now, of course, I will have to add the caveat that I can't say definitively that a bit of overstating might not have been part of the provider's plans but that's another point for discussion and as you might expect there's always a way to cross check most provided information. And, of course, there is always the possibility that the downstream user asked for a little bit more than he really thought that he needed hoping that it would provide some particular benefits for him in the future.

Another basic concept for consideration in looking over processes as you're considering their development is hold volumes that are needed to operate the plant. Certainly we run into a variety of conditions that exist in processing today. In some cases it's appropriate to consider raw materials delivered on a JIT basis, just in time, directly to production vessels. Sometimes the delivery methods can be an effective way of receiving materials in certain quantities or at certain times and there is also the concept of the transportation scheduling on how they're delivered.

Again, as a small aside one plant that I worked in was within about 40 miles of a manufacturer of raw material. They found that they had an option of either of several methods of transportation. One of them was rail transportation. One of them was trucks. Early in their work they found that the rail transportation for the 40 miles was often taking six to eight days and a truck shipment would, of course, only take a few hours to make the transfer between the plants. The problems of cost of materials tied up and the risk that was run in having materials sit for long periods of time in unknown conditions tended to force them toward the faster shipping but in this case the rail line was very interested in maintaining the business and came back with a proposal and the continuing performance to back it up of guaranteeing that material shipped in the bulk form that was, of course, more convenient to transfer into storage and to use from storage would take no longer than three days and this was one of the mitigating circumstances that led them to continue in over 90% of the operation with rail transfer.

Another small factor in the idea of hold volumes is whether or not there is some kind of aging or minor properties change or adjustment that can be done in the receiving or in the transportation function that will improve the processing. Sometimes just the idea of aging can be worthwhile. Certainly the idea, as we said, of properties adjustment and final properties adjustment. Several storage vessels give you the opportunity to do that and be sure that a raw material is of a certain condition just before its use.

Hold volumes, of course, are significant on the discharge end also and the question would come in can a material that is being prepared be discharged directly from a processing vessel into the transportation method for shipment? Now, whether this be drums or larger containers or is there a particular reason to minimize handling and go directly to drums? These kinds of considerations, of course, will have direct influences on the equipment needed for processing and for packaging and lead to a question of whether a simplified version of the vessel should be used for the source to a packaging unit, or transfer unit, and allow the main reactor vessel to go back into the primary processing.

Sometimes the physical form of the material will affect the selection of what vessels to use and in what sequence. If a material is made in a very thick or pasty condition, again, it may be of significant advantage to package it or to put it into some kind of a transfer method directly from its initial processing so that the problems of recovery and repumping and rehandling are reduced.

And then, of course, we run into a final consideration on hold volumes are materials that have particular time life concerns. Sometimes a material will begin a dimerization during holding that would be detrimental to processing. Sometimes they begin more significant polymerizations where temperature control and other modifiers in the material and their concentration become very significant. Those of you that have industries where this is important certainly will recognize this question and there are a number of them out there. Another aspect of something like that is a product or raw material, either one, that does indeed have something within it that is significant from a time life of holding in a particular vessel. It may have nothing at all to do with a change in physical form or a polymerization. It may just have to do with a problem of settling in transfer and from that reason you would much prefer to minimize any particular handling so hold volumes are kept to a minimum and materials processed as soon as possible.

Well, we've laid some ground work, set some conditions that should be considered as you begin looking at the process. Let's begin now with a couple of stories that discuss overall looks at processing that hopefully have some interesting concepts for you to consider and can give you a little idea of how to get started into some of these process reviews.

A number of years ago I had the opportunity to work with a company who was building a rather large project outside the United States. As I began looking at the overall processing of the facility one of the questions that came up was the idea of the power that would be supplied for the plant and in general terms I was to have some responsibility for making sure that the material handling and supplies for that power generation was appropriate. Since the facility was outside the country and was new it had to be independently powered separated from the power grid of the host country and the election was made to use an oil fired power plant. There were several

other process activities that required some considerable oil volumes too. As I began discussing with the plant personnel the handling and receiving of the oil I found that they were looking to transport the oil from a port facility to the plant in rail cars. And as I looked at this and realized the volumes that were going to be involved in the oil transfer it very soon became obvious that they had no concept of the requirements for the number of cars, and the amount of equipment and the amount of space that would be necessary to load and transport the volumes of oil necessary in rail cars.

When pointing this out fortunately or unfortunately I had been experienced in a plant previous to that where we had some considerable rail handling capabilities. It became very obvious that in the 13-15 miles of rail line between the receiving port and the operating plant they probably would not have had sufficient trackage to keep the total volume of cars that would have been required in order to allow loading and unloading and transportation all at the same time.

It was very frustrating to have to bring this up relatively late in the project but we were in the fortunate circumstance that there was a complete ownership of right away sufficient to make the changes that were necessary and it turned out that one rather large pump of sufficient head could be used to transport the oil from the receiving facility to the plant in a pipeline but, of course, now it had to be done on a crash basis.

The pipe line was put in parallel with the rail lines and, of course, some additional piping at the port and the plant in order to be able to get from the receiving vessels into the feed lines to the pump and from the discharge end of the pump to the receiving vessels on the plant end. And, of course, since there were two varieties of oil that had to be used, one for the boilers and one of much higher quality for some other special processing, the materials had to be separated and, of course, pigging involvements and potential cleaning, pig launching stations, and receiving stations and some various time arrangements worked out but fortunately with about a year to a year and a quarter available from the time this was first necessary and noticed the arrangements contracting for the facilities, purchasing of the equipment was all worked out and put in place by the time it started.

So in this case I would suggest that it was where we ran into an “Out”, a particular early concern had to be taken out. Of course, it resulted in a replacement, which could be considered both an “In” and an “Out” but the process was significantly improved by recognizing that certain early plans were inappropriate to the facility and to the over all project.

For a little humor on the background there was a personal note that was involved with it too that since I happened to be the person who instigated the question and the problem I think that it was decided at other levels that it was inappropriate for me to have any part of the solution to the problem. So it was turned over to one of my technical staff mates who very quickly then came to me and asked if I had any information on the development and installation of pipelines, which fortunately I happened to have at the time. So my involvement was a little bit deeper than I think some of the upper management expected at the time.

And also as a sidelight to this it certainly is important to recognize that in many cases the ideas and the considerations and the questions will require some experience in order to understand

whether they are appropriate questions, appropriate concerns or whether it's just something that the reviewer is unfamiliar with. I really don't have an answer for you for that kind of situation and in this oil pipeline example versus the rail cars I was very fortunate that I had been exposed to the problem of receiving and handling rather large volumes of materials in a prior plant operation. So it was easy for me to recognize the relative problems. That, of course, is part of the reason why I'm preparing this tape and this course for you in hopes that those of you that hear things like this will recognize, and remember and be aware as you look at things in the future of a few more things that can save you a lot of difficulty when it comes time to actually initiate operation and begin looking for the return on the investment.

I am going to review now a concept that led to what could be considered definitely an in for activities in process review and for this one I will reach outside of my particular experiences, although we'll discuss many of those later, and look to a very interesting one that I found in an article that was written by D.Q. Kern, the author of the very popular heat transfer text called "Heat Transmission." And this was discussed in an article that he wrote called "Speculative Process Design." It was published in *Chemical Engineering Magazine* originally in 5 October 1959.

The article starts with several excellent reviews of basic concepts in chemical engineering processes and process analysis and then goes into a discussion of particular applications that Mr. Kern felt appropriate to his discussions and one of these had to do with heat exchangers. Those of us who have worked with heat exchangers always understand that one of the key factors in the continuing use of a heat exchanger is the continuing availability of the expected surface area and the continuing performance of the heat transfer coefficients in the range for which the equipment was designed and selected. And that one of the problems with this is accumulation of dirt or fouling within the exchanger.

Mr. Kern points out that in one plant that he visited frequently that he recognized this problem and since this was a large plant with continuous operation and very specific needs that those occasions where, for one reason or another, there were small process slow downs seemed to be the periods of time where fouling increased, or at least the rate increased, in the heat exchangers that were so critical to the plant operation. In reviewing this he then recognized that if the velocities were maintained at a higher level during the periods of difficulties in other areas that possibly they could reduce the rate of fouling and improve the overall process longevity between conditions created as a problem by the heat exchangers themselves. And for this he suggested the installation of pumps near the exchangers that could be used to recirculate liquids within the exchangers and be sure to maintain a minimum flow in order to keep a maximum velocity and prevent the fouling that occurs during low velocity periods.

He apparently went through quite a review and explanation of the process modification to the plant personnel and made a rather significant point of the potential improvements and suggested that this kind of design and performance, or addition, would indeed save considerable funds in the plant in clean out of the heat exchangers in the long run. Unfortunately, the article does not summarize what happened when this activity was actually started and installed into the plant but his arguments looked very solid and seemed to indicate that there are some very considerable

gains that could be made by making sure that all facilities do maintain reasonable flows at all times.

There, of course, would be two ways of achieving this and one of these is just continually maintaining the flow of the various materials on each side of the exchanger at a minimum velocity. However, his recommendation, and I think a good one, was the recycle of some of the discharge of the exchangers of either of the flow rates back to the inlet side in order to maintain the velocity thereby allowing the flows to be reduced overall on certain occasions and yet maintain the same uniform flow for conditions inside the exchanger and prevent the deposition of materials and fouling that can occur during low flow periods and periods where some tubes can be receiving less flow that can be expected in the average design due to a lack of demand for cross sectional area for a given passage rate through the exchanger.

Basic concepts such as this were the genesis of the article written by Mr. Carroll that I've indicated is part of the package with these tapes but I would like to take a portion of that article now to give you some additional oversight not biased by my particular experience that I hope will be of some interest to you.

Now, Mr. Carroll says; ...“that some years ago the company for which I labored hired a consultant to survey their operations in the fine chemical field. This expert had concluded his studies and was pushing on the next day to a new assignment. Being in an expansive mood he favored me with a few pearls of wisdom from his long experience. Charlie, he said, I will tell you the secret of my success. As I listened with bated breath he unfolded a tale that went something like this. When I am called in to survey an operation, early in the game I request a plant tour. I make it a point to be introduced to as many as possible of the assistant production heads and engineers who are familiar with operations. I then contact them individually and ask for their suggestions on how to improve operations. After a suitable period of time I select the most promising of these suggestions, incorporate them in my report and the job is done. “

He went on to explain that practically every sub-department head who is worth his salt had spent lots of time considering ways to make the operations of his department more efficient. Very likely he had presented suggestions along this line to his superiors from time to time. The combination of poor presentation on his part and resistance from above had resulted in the adoption of very few of them. Therefore, allowed my friend, he as a consultant was performing a necessary and useful function in evaluating this wealth of information and bringing it to the attention of management. The fact that it costs them \$100 a day, (certainly this article was written some time ago,) for him to discover information from which was there all the time was only incidental. The important thing was the result. He was, he said, giving value for wages received. I could not help but agree with him.”

What is the moral of this story to you? It goes, I believe, something like this. Assume that you are a staff process engineer in the J.R. Big Chemical Company with a problem of designing an installation to double the production of Framus Dioxide. So what do you do? Acting like a good well trained engineer you get out the flow sheet, talk to a couple of boys in the department who did the last job in the framus plant and you have most of the dope you need. A few quick checks with the mechanical instrument and structural boys and you are ready for the draftsman.

Subsequently, you send a set of check prints to the super of the framus plant and get them back with his signature and you're ready for the estimator. And there you have it, a nice neat package. Sure it will cost a lot of money but what is cheap nowadays? Hasn't the Marshall and Stevens Index gone up several percent a year since the last time we expanded the framus plant? Besides everyone knows it will work. It's just a matter of adding a few tanks, pumps and a new reactor just like those already installed. So there you are a good engineer doing a fine competent job for good old J.R. Big; or are you? Are you sure that there isn't another way to make the extra amount of framus dioxide and do it for a lot less money. Could it be done for \$100,000 less, \$250,000 less or maybe even a million dollars less?

Try looking at it this way. How much framus dioxide does the company have to sell to make an extra \$100,000 that you might save? Well, if it's like most chemical products these days J.R. Bigg would have to sell more than \$1 million worth. Okay, so what is the answer? How do you go about doing this poor boy, high profit plant? Let's start with our friend the consultant. What did he do? He spent a lot of time out in the plant talking to the people who operate the place. The department head, his assistant, the foreman, even the operators.

Let's go back to your standard procedure for design as outlined above. About this time you have familiarized yourself with the flow sheet at the framus plant. Get off your well padded chair and go out and look at the full scale model. Get to know the people, the machinery and the product first hand. If it's a continuous process there is no law against dropping in during the night shift a few times. You would be surprised what a problem a leaky valve can be at 2:00 a.m. on Sunday. Then make a real effort to find all the available information about the framus process. Look up some of the boys in research who worked on the original pilot plant. Spend a couple of days in the library and do a little literature search on your own. Then comes the really important part; take a long look at yourself and ask a lot of questions like can't I substitute wood tanks for this rubber lined tanks? Maybe if I really figure the pressure drop in that line it can be three inch instead of four inch. How about schedule 5 stainless pipe instead of schedule 40? Do we really need a recording controller with automatic reset and derivative on the process tank?

Sure, it's hard exactly work but when you finish you know you have done something. Maybe you have pared your original estimate by \$250,000. Four jobs like that and you've saved a million dollars and probably \$10 million in sales for the company."

Returning now to some additional real system examples; let's look at an idea that I ran into with instrumentations and its availability in order to be able to modify it or adjust it during operation. In a large plant that I worked in there were some very large evaporator systems. At the end of the evaporator systems, of course, there were flash tanks, the barometric flash tanks, to allow for the final releases. And they were elevated since the low end pressure was very low; elevated to allow sufficient NPSH to the pump-out pumps. The levels in those tanks, of course, was critical to the operation of the pumps and also significant to the overall knowledge of the performance of the process systems. Since the tanks were significantly elevated in the air the sensing points there also significantly elevated. In looking at the original design for the plants one of the things that was noticed and was commented on to the designers is that some access would need to be made to those level sensing transmitters so that performance and adjustments could be

sufficiently completed and accessed. The designer said no we're going to provide for that. We're going to provide sensing and access connections at the ground level.

Well, having been in plant operations for a while; myself and several others recognized that this was not going to work. We unfortunately knew by the time that we had pressed this argument for a while that it was not going to be achieved and we did exactly the requirement that the designers of these level systems and selectors of the placement would be in the field at start up.

So, of course, the appropriate start up date arrived, and we were all standing there with the units coming on line, all of the proper flows, various indications on some of those, and finally the idea of when to turn on the pump-out pumps. As we watched for awhile, we finally got some semblance of indication of level in the pump-off tanks, but of course we wanted to be sure that we had sufficient level.

So we turned to the installers, and we said, "All right, in order to be sure what the tank levels are, can you make sure that we do have sufficient head in the tank?" They immediately turned to the transmitters and said, "Why yes, we certainly do. There's 30% indication." I said, "Well, are we sure that that's the level in the tank?" They said, "Well, yes." I said, "Well, I'd like for you to verify that." Fortunately, at that time, one of the construction instrument personnel were coming by. Of course, I knew that the installers would have a lot more faith in someone on their payroll, rather than someone on the plant payroll, so we invited the gentleman to come over and take a look at the conditions.

He asked the same questions, we went over and looked at the transmitter with him. He indicated, "The transmitter indicates 30%." We said, "Well, does that mean that there is 30% in the tank?" He said, "Well, I really wouldn't know until I can get up and check the transmitter positions on the sides of the tank," which, of course, is what we had suggested quite some time ago, during the initial design. In this particular case, the designers and installers were very reasonable in agreeing that, yes, now they would see that those kind of access points would be provided, and of course, they were added to the vessel.

Obviously, we, as the operating plant, ended up paying for this problem, since a change like that is a significant change, regardless of the fact that it was argued originally, and asked for, and so on. But the point is that there are many times where it's very difficult to achieve an understanding of the reality of the problem until someone has the operating experience to know it. The operating experience to know it comes from people who have been in the plant, which very quickly, goes back to many of the original discussions of going out and reviewing with people in the plant that have to serve it, to understand the things that are necessary to help and improve their ability to work with the overall facility, or the modifications to the facility, when it comes at some later time.

This is the end of side one, tape one, of the Ins and Outs of Chemical Engineering.

Tape 1 – Side 2

This is tape one, side two of the Professional Development Hour Course, titled The Ins and Outs of Chemical Process Engineering by Ed Hardin.

At this point it's appropriate to get into a discussion of capital cost development for projects. We've discussed many of the little things that can occur in projects as you start looking at them and talked about some vignettes of problems that have developed at the start of projects but let's start looking at the idea of how cost estimates and project estimates are developed.

Mr. Buchannan in his article on how to avoid common pitfalls in making cost estimates discusses a lot of this and he brings out an idea that's always worth considering as we start looking at estimates and that's how did the estimate start coming together? Certainly we talked before about the idea of getting together with knowledgeable people in a project and using their ideas to develop a flow sheet and to get ready to move forward with a project but now we need to look more specifically at who those people might be and our little discussion earlier about the consultant going into an actual operating plant brought out the idea of using the people in the plant. This is a very good way, of course. However, on occasion there are new products that have to be considered. And in looking at a new product as it's being developed we're now usually confronted with the idea that it's being developed away from a plant and probably by people who's responsibility it is to take limited information and develop it into a plant estimate and flow sheet arrangement.

Now, certainly people with good experience in this area are valuable, valuable tools in developing any project. But we have to recognize that now and then sometimes an estimate is going to have a little more limited value as it comes out of one of these procedures. Certainly an easy question for an engineer to begin criticizing or reviewing is the idea of some people in a laboratory coming up with a project and making an estimate of cost. If you go into various cost estimating books, such as "Aries and Newton" or "Peters Capital Plant Costs" or "Peters and Timmerhouse," any one of these things, you'll find many references to simple ways of developing costs estimates.

One of the oldest that's always fun to look at is to project a plant size and the quantity of material that will be produced in that plant in terms of number of pounds per year and then find out what that material is currently selling for or make a projection of some kind as to what you think that material will sell for on a dollars per pound basis or cents per pound and multiply those two numbers together. And that will give you a capital cost estimate. This, of course, is a very, very preliminary estimate. With conditions as they existed 60, 70, 80 years ago. It might have had a little bit more validity and being able to use something like that but under current conditions of additional reviews, additional bureaucratic and legal requirements that go into a plant and recognizing a number of other factors that are played in there, certainly an estimate like that could easily be off by factors of two, or three or even more.

So we don't like to use those kinds of estimates. We go to a little bit better varieties and we look to the idea of people who are familiar with processes and with the kinds of things that are being done and use their ideas. And then often go to booklets of is the project primarily a stirred tank project and under these kind of conditions if you're normally using glass reactors and stainless steel pipe you can use a couple of factors and you can then add to that the idea of the different

material costs and go to overall cost estimates from, again, books like Peters and Timmerhouse or *Peters Chemical Engineers Handbook* and find normal distributions. Cost might be somewhere between 25 and 40% of a capital cost.

Piping costs might be from 12 to 20% of a capital cost, and electrical costs might be 10-12% and instrumentation costs might be 10-15% and on and on. And, of course estimates now particularly of environmental costs get to be very, very significant. So here we have now another variety. We now have people who are responsible for this estimate. They know where to search the information that we've been talking about and they develop a cost estimate. And, of course, then everybody looks at something like this and they put on a "contingency" or an "error factor" or so on.

And even there, there are very wide ranging methods for coming up with a number that's appropriate to use for that distribution number. Something that would take a variety of listings of the equipment and the various costs that the equipment could be projected at and come up with a whole series of estimates based on using probability factors and a number of other things and come up with numbers that give you an "S" curve of costs from what would happen if everything worked perfectly, which we know it never will, to what would happen if everything worked just horribly bad and if you use that "S" curve and you throw a line out at some 90, or 95 or 98% probability you can then compare that in the figure where those lines intersect and come up with an estimate and a projected contingency and, of course, again the best ideas, the best plans, the best experience of the people that are involved in the project are not brought into bear because they are the ones who must put in the ranges of the equipment costs, the probabilities of certain things happening and so on. And making some reasonable estimates of what are the other requirements going to be. And when all these things come in now you have another way of developing a cost estimate.

All of these things have their place as projects are being evaluated and corporate boards then like to get involved in taking a look at the numbers and what numbers come out and what the probable sales costs are and about how much it will cost to get working capital into this. How much in the way of inventories and transfer costs and selling expenses and overall management factors. All of these things then get added in and other things are brought up to the estimate.

Certainly here one of the things that's very interesting for me to bring up and offer as a little aside to this was another article that was done in *Chemical Engineering Magazine* several years ago where a young fellow was put into the position of having to take estimates that were developed in this way and to evaluate them and turn them over to a manager. And he was looking for the idea of a factor on equipment costs and what to use. And certainly an older gentleman that was experienced in the company began looking at him and trying to explain these things and finally came down and said well, the factor that you should use is you find out what the boss thinks it's going to cost and you divide that by the cost of the capital equipment that you come up with and you've got the best factor you can use. Well, this is a little suspicious as I'm sure all of you recognize. And, of course, involved in this thing too was who were you talking to, how many more pieces of equipment of a given size or a given type are you going to add? Are you going to add things for purification, for recycle? And then, of course, in the cost

estimate as it comes together you then give management the opportunity to take these things out because they're very expensive and then they can feel they really don't need to do these things.

So many of the games get played with cost estimates, it gets a little frustrating as you start looking at these. As initial ideas pass along from these cost estimates and you do finally move forward into the idea of a real potential project and coming up with something in the way of a serious cost estimate it now becomes important to get involved with the people both in the plant and in the corporation and sometimes out of the corporation to get involved with this.

And this is where our friends the British used to quite regularly use one of the general criteria and that is that an engineering company now be brought in and they be given the responsibility for taking estimates that have been prepared, reviewing them and developing a finished cost estimate and a finished developed cost estimate. That was quite regularly done here in the United States for a period of time too but it seemed to carry on a little bit longer in England based on some exposure that I've had with some European companies. I suspect that, as in many cases, that's changing over there as well as it here.

In any event the question now comes to the idea of let's put together an estimate that really reflects what we think is going to happen. And so now we come down to adding, and subtracting and seriously considering the ideas initially of the kind of process, the kind of processing delivery methods, packaging, all of the other things that go along with this. However, as we start doing this we now start running into a number of questions that are more typical of projects and activities today than they were 30-40 years ago. And these are the various regulations that come in both of a safety and environmental nature so that those things are appropriately treated.

An early question that would come in is the idea of how much time and how much effort is it going to require to do preliminary hazops on the process to make sure that it's workable. Another serious area of consideration is the idea of a number of years ago that the P&IDs would often show a situation of "to safe venting." Not quite as acceptable an idea anymore. Now there has to be a consideration in there of is that safe venting something that agrees with environmental discharge regulations? How many places do we really need to have discharges? What kind of absorption, or recovery or recycle of materials can help us reduce the number of cases of discharge that we must both recognize and treat and the number of cases that will need to be considered in permit development?

This is a place where the various project development people get very, very sensitive because now here their brainchild, the serious emotional involvement that they have with developing a project is being scrutinized by these "outsiders." These people who do not understand the significance of my process and my processing and apply heartless considerations to how it will be treated, how it will be handled, how it will be vented, what really needs to be done with it and so on.

I would throw in a little tale here of, again, a project that I was involved in as a operations supervisor a number of years ago where the product that I was responsible for making was a byproduct and used kind of a second run material that was normally produced in the plant. And using this material and doing a processing with it we were able to make an entirely different

formulation product and different form of product as a prime material that was not intended to be used in the same way as the original material. So there were very good reasons for calling it a whole new product and prime material.

As we began working at this we recognized that quite regularly in the original plant production conditions that there were many times that a material was inappropriate for either process under the basic criteria that was started but by working among several of us we found that by a good critical analysis of the material and by doing a very rapid process addition of this material and bringing it in that we could take an off spec material that was ready to be discarded and abandoned and would, of course, cost money to be discarded and abandoned. And we could indeed convert it in to the product that I was responsible for manufacturing.

Well, of course, having done this now for some six, or eight months or so my next up the line supervisor came to me one day and said, Ed you know, he says you're running a serious risk out there. You're taking really bad material from somebody else and you're making them look good. And I said well, it's kind of making us look good too isn't it because we're getting a very reasonable cost on the material and we're putting out a prime product that is performing in every way that we expect it to. And he said, yeah but, you know they might start playing games with you and send you the wrong material. Again, I offered the critique that we very critically evaluate this over again. He said well, just recognize that if you're ever out there hanging on that hook you're going to hang alone.

Well, that, of course, was a sobering concept to be reminded of but among the several of us that had had the experience, and the background and had worked out these methods of proceeding and moving forward we did indeed come to a good working relationship and continued to use that material and to make a lot of money for the company. And instead of having a material that was going to cost \$0.02 to \$0.03 a pound or quite even as much as \$0.05 a pound to discard we were able to take that material and turn it into a \$0.40 a pound sold product. That's a pretty good swing on material and, of course, that amounted to some 25-30% of our total production requirements. So we certainly weren't going into it blind. We did it with some controls but, again, we're back to the idea of it depends on the information. You must work together. You must find people who are willing to work and provide you with reliable information. And so we get back into the idea of people as they come together with processes they must recognize that certainly their knowledge of certain parts of the process is very significant. They also recognize that there are other people that come to the table and come bring help to this project that bring some rather significant knowledge too and are trying to share it in the best way for all involved.

Mr. Buchanan gets a little bit more specific in how he handles comments on these cost estimate developments. And I'm going to read to you now from a portion of his article where he says, "During the long evolution process from conception to commercialization of every proposed new venture many estimates must be made of probable investment requirements and potential profitability. A number of mathematical and statistical methods have been developed for appraising the accuracy, and cost and profitability of estimates. However, these approaches are of little value when making an evaluation estimate. This is an estimate made in the early stages of a venture on the basis of very limited information. Actually, experience has shown that significant error in evaluation estimates usually result from a lack of appreciation of the facilities

required for those processes or a mistake in conception of facilities rather than from incorrect pricing of equipment."

"Let us examine how such estimates are usually prepared to see why and how they go wrong. As the venture approaches commercialization and there's normally active participation by many individuals with a variety of skills and experiences. However, during early evaluation this is rarely feasible. Evaluation estimates are thus normally based on processes concepts agreed upon by research chemists and a "cost engineer" with little opportunity to benefit from the experience of others except perhaps by obtaining answers to specific questions. Basically then evaluation estimates are derived from process concepts based on information received from relatively few individuals. Yet these individuals tell only what their specific backgrounds indicate as pertinent to the evaluation and even this must be done in words that may well mean one thing to them and another to the cost engineer. In addition, misunderstanding or fear of the costing function may inhibit these individuals from freely passing on information. Communication is thus a basic problem and appraising the effectiveness of communication provides a good idea as to the validity of the evaluation estimates."

"For example, let us consider the viewpoint of a research chemist who has devised an ingenious new process only to find that management will not authorize money for development without an economic evaluation while the cost engineer may consider his function as a puppeteer predetermining management action by reports and evaluations. The research chemist might view him as a potential executioner of an important process. This researcher will soon learn or be told by his colleagues that the cost engineer is indeed an expert but an expert at making appear expensive the simple things that any intelligent chemist can easily do in the laboratory with readily available compressed air, dry ice, acetone and glassware left over from a project killed two years ago. Clearly the company's interest requires that the engineers be told as little as possible if the potentially profitable process is to survive the evaluation."

"Similarly the purchasing agent, production supervisor, maintenance engineers, safety engineers, plant designer and salesman will each have an individual viewpoint toward the functions of the cost engineer as well as towards these other functions. There are no right or wrong viewpoints only differing viewpoints where the differences arise from the relative importance each individual's background causes him to attach to the various factors involved."

Here I'll make a little aside because this attitude is very Nietzsche in philosophical content. Nietzsche, in summary, in several books I've read is commented to have made the statement that there is no truth. There are only opinions and that essentially was what was addressed before. However, if we then go back and ask if Nietzsche was right then it must be true; in which case his original evaluation that there are no truths is, in fact, wrong. So his evaluation starts off with an error and compounds it.

We still get back to the point that we must recognize, as we discussed earlier, that there are a lot of viewpoints. Some of them are based on solid observation, and background and opinion. Some of them are based on a personal fear and a lack of understanding of what's going on. So again we get back to the idea that everybody has to be attuned to a common goal and willing to work together.

Now, let's go back to continuing the reading and going on from Mr. Buchanan. "The engineer making an economic evaluation must be able to examine the venture from various viewpoints to be sure he has a complete and feasible concept as a basis for his estimate. As such, examinations disclose no serious emissions. It is reasonably safe to assume the estimate of cost is valid."

"Let us consider the viewpoint of the purchasing agent regarding a proposed new venture. He would undoubtedly ask can the raw materials be purchased to desired specifications. How large a section of the market is represented by our requirements for each material? How stable are supply and prices? How many reliable sources of data supply exist? A study was made some time ago of the possible manufacture of a new product starting from the salt of a rare medal. Early evaluations were made on the basis of published prices and a quite attractive venture bloomed, at least on paper. However, development work was discontinued when it was discovered that the process would require several times the known world supply of the medal. Adopt the purchasing agent's viewpoint. Be sure raw materials are not out of this world."

I would also add to that discussion a project that I got involved in where a product was projected and it came up with a byproduct and the byproduct had a value on the market. And so it was proposed that the project be justified on the basis of the sales of the byproduct. It took a while for people to understand, however, that the rate of manufacturing the byproduct was, again, into the idea of 8-10 times the known world consumption at that time of the byproduct. Therefore, the price of sales for the byproduct would no doubt drop significantly when such a vast increase in quantity was available. So it finally came to the understanding of everybody involved that this project was not viable on the basis of selling the byproduct.

Continuing on into other conditions to consider for projects; one of the early considerations to consider for any project today that has to be brought up and recognized is the environmental conditions. And the basic idea is let's don't get surprised by them as they come in. As a little suggestion of something like that, although it's not particularly chemically related it's still of interest to recognize how people can get pinched by their own problem. There was a planned expansion one time for the Midland Odessa Airport in Texas. And everybody was ready to do this and somebody came up with the idea that an environmental assessment was needed. So the project ended up dropping back for a considerable period of time while a full environmental assessment was done and that finally was completed at some significant cost and delay to the project. And the project was then authorized and moved ahead.

To be followed relative quickly by a request from the person who initiated the complaint and the request for the environmental assessment that his department of government should be supplied with special parking places. To which the manager of the airport and the development function that was existing there returned to him and said fine we'll consider it when you bring us an environmental impact statement and thorough environmental assessment of the need for your parking spaces; so questions always do come in there.

We can also go back to our friend Mr. Buchanan and see a few comments of his along these same lines where he makes the specific comments, "The increasing complexity of state and federal regulations concerning waste disposal has elevated the status of experts known as waste

disposal specialists. These individuals are very aware of the significance of small arrows on process flow sheets with such innocent labels as 'to vent', 'to ditch', 'to burning', 'to waste', 'to atmosphere', etc. Their viewpoints are necessary in preparing an evaluation estimate. Many years ago a young engineer made an evaluation of a proposed process for producing a gaseous product by the reaction of an acid with a solid raw material. At the same time the reaction produced the solid byproduct that was to be discarded. The evaluation indicated large profits from such a venture. The whole proposal finally died when it was found that this waste material had to be trucked five miles and land had to be purchased for the waste collection. Beware of small arrows with innocent labels. Think through each process to be sure all outgoing streams are provided for. Last, but not least, examine each proposed venture from the viewpoint of the company's salesman. Do we have any advantage over competition? Can adequate quality be maintained? Can deliveries be made as needed? Is packaging suitable for the customer's needs?"

"Evaluation estimates should, of course, include all facilities and operating costs necessary to put the product in the form that the salesman expected when he made his forecast of dollar sales. Not too long ago a proposal was made that looked extremely attractive until it was found that the investment and operating cost estimates provided for tank cars of product while the sales forecast assumed aerosol cans. The project looked much less attractive after adding facilities and costs for aerosol packaging. Take the salesman's viewpoint. Be sure you provide facilities to place on the shelf a product that the customer wants in the form he wants it."

Another significant area in any siting or development of a plant cost is to consider the area where the plant will be located. Any number of studies have been done on siting plants and picking particular locations for plants. And, of course, one of the things that's always kind of interesting in considering plant locations is the idea of where is the final customer. And certainly one of the things that has kept the rust belt, if we want to call it that, but the Michigan, Ohio, Indiana area very popular for the development of plant sites is the fact that given a circle of four or five hundred miles radius some 50 or 60% of the potential customer base for almost anything fits with that 500 mile circle that would include Ohio, Indiana, Michigan and, obviously, Kentucky, and Pennsylvania and Illinois. So if that's where you're looking to sell the product. If that's where a bit part of the consumer base is, certainly a plant somewhere in that area is of interest. If the only place that the customer lives that's going to buy this thing is somewhere south of Phoenix in Arizona it's not particularly material to make the plant in Ohio unless that is exactly where the source of raw material is. So, again, factors will come into play that will bear significant consideration.

And from a general standpoint I would suggest the idea of Niagara Falls New York as a concern for location and what should be done. Certainly those of my particular age group and hopefully some of younger engineers out there are aware of the concept of the Love Canal. Hooker Chemical put together a plant and operated very successfully in the area for a long time but they did have some waste products. Ultimately the areas where several plants they had built looked pretty attractive to someone for building and in various ways the land area was transferred from Hooker to a local government to allow development; but there were several specific requirements that were put on there. And certain of those requirements were that the areas where Hooker had been building plants and storing waste materials were not to have been touched and

that was very clearly spelled out in many of the documents that covered the transfer of the material.

The first thing the local government did in turning it over to a development was allow a contractor to go in and bulldoze the area. Of course, the next thing that happened and the obvious thing that we've all heard and read about was the worst possible decision that could be made, that a school should be put right in the middle of the area, which happened to be right over where the worst waste materials were stored and from this the many problems of the Love Canal came up.

No one likes to see anything like that develop, and nobody likes to see the legal problems that come from it and nobody likes to be caught in the middle of the legal, or plant or political problems that can come from a decision such as that. Certainly the long, long ago problem of the Teapot Dome scandal and the potential for shale oil in the central United States was a god awful problem of political consequences. It is interesting now that in Northern Alberta and Saskatchewan the Athabasca tar sands are being developed and are being successfully developed. Certainly there is a potential for the oil shale sands of the central United States to be considered again. Obviously Tea Pot Dome is going to have a big affect on how people look at these things.

And as we speak about oil and oil related activities we can also begin to recognize that even home owners are now being affected by this problem; certainly people in the northeast who are selling homes and in a number of other areas where heating oil was popular as a heating method. Anyone who happened to have a long time storage tank whether it be above ground or under ground is now being faced with the question of what kind of quality did that tank have over time and do they have an environmental cleanup problem where they have and used their oil tank for the loading and unloading.

And this, of course, brings in an opportunity for another little vignette that the idea of recovery of ground areas is handled in many ways now and digging up all the materials and transferring it somewhere else for treatment and so on is one of the ways it's used but there is a method called in situ remediation. And it's kind of curious that that in situ remediation was actually, and again I do not have documentation on this but I'll still suggest it having read it in several places that it was developed at Oak Ridge Tennessee. That there was an old laboratory site that actually needed to be used for a new facility location but people began looking at it and realizing that there was significant contaminations. And someone there in the Oak Ridge laboratory area came up and devised a method of putting some collection basins in the near center of the area of concern and putting a liquid circulation loop with liquid placed in a surrounding area, surrounding the area of concern. And then collecting this and treating it through a biological treatment box. And over a period of several months the ground area was flushed clean and the treatment boxes and treatment methods that they used on it removed the contaminant problems that they had and they then had a very small thing to get rid of, namely the boxes of the treatment facilities that they used. And thus was developed the magic of in situ remediation.

It's somewhat disheartening to go through the examples as I've provided here and recognize the significant involvement and cost that came out of what seemed to be relatively minor decisions but that's one of the natures of missing little items in early considerations of projects.

In any one of these situations a simple early decision, early discussion and recognition by all involved of some pieces of information would have prevented considerable later aggravation, and involvement and trouble for everybody that was involved. And, again, we go back to the idea of the matter of communication among people and how it is kept.

We'll finish off this tape with a little final discussion from our friend Mr. Buchanan on a simple item that gives an example like that. And again I quote from his article, "Since it is always difficult for persons from diverse backgrounds to establish effective communications, do not hesitate to ask simple questions and be sure to explain why you are asking them.

Many years ago I sat in the office of a research chemist discussing a mutual problem. It was almost quitting time on Friday afternoon when an associate from the accounting office called on the phone to ask a chemist what would dissolve dried ink. With a minimum interruption my chemist friend suggested ethyl acetate. We didn't manage to solve our problems Friday afternoon and reconvened Monday morning for further discussion. In the middle of this I walked the accountant with a beaker of dark fluid in one hand containing a gold pen point. His only comment was you didn't tell me it would dissolve the pen too. Try to be sure that the answer you get will fit your problems."

"In summary, the problem of validity of evaluation estimates is inseparably bound to the problem of understanding and communicating ideas between people with different backgrounds and viewpoints. Look questioningly at any preliminary evaluations, reason through each proposed process to be sure that the costs have been included for every necessary operation. Expect the unexpected and include cost to cover it, particularly on safety items. Ask searching questions but at the same time try to give sufficient reasons for questioning so that others will understand and answer completely."

And certainly that's the emphasis in almost everything that we as engineers do when considering projects and what should be in a project and what should be out of it. The important thing is to come to an understanding, come to a good combination of information. Write it down. Document it as necessary to be sure that everybody understands what's involved. Spend a little time discussing it and recognize that there are too many places where people can take simple decisions that they'd like to have come true and then end up running into significant problems later on. And nobody likes to get caught in those kinds of conditions and we all look to come up with a reasonable estimate for a good plant so that everybody can be happy with it. The chemist can be happy that his product is brought to fruition. The engineers can be happy that the project that they put together fits, goes in easily, gets build simply, has the right materials. And the operating people can be happy that they can walk out and make a quality product without risking the lives of operators and maintenance people in order to be able to do it. And that where there are special needs that they can be prepared and ready to address those needs whenever the time comes that they are forced into rebuilding, or modifying, or repairing or correcting anything that might occur in the future operating plant.

This now is the end of Tape 1, Side 2 of the Professional Development Hour Course, The Ins and Outs of Chemical Engineering. Please change to the next disk.

Tape 2 – Side 1; Disk 3 (Ins & Outs of Chemical Engineering – Ed Hardin)

This is the beginning of Tape 2, Side 1 of “The Ins and Outs of Chemical Engineering,” a three-hour Professional Development Hour Course provided by Ed Hardin. I am a registered professional engineer in the State of North Carolina.

To continue with our discussion of developing plants and the things that chemical engineers do, I’m going to move on now to another discussion, and a discussion in a different way, of how to do things in chemical plants.

A gentleman by the name of Charles E. Carol wrote an article some time ago, included in the package of reference information, called “You Can Be a Smarter Chemical Engineer.” It was published in Chemical Engineering Magazine some period of time ago – I’m sorry I don’t have the date in front of me right now.

Mr. Carol makes some very interesting observations as he discusses what goes on in plant and project development, and he suggests and I quote: “Assume that you are a staff process engineer in the J.R. Bigg chemical company, with the problem of designing an installation to double the production of Framus Dioxide.” (Obviously a synthetic material.)

So what do you do? Acting like a good well-trained engineer you get out the flow sheet, talk to a couple of boys in the department who did the last job on the Framus plant, and you have most of the dope you need.

You see how quickly we get back to the question of getting together with people and making sure that your information is pretty good? There are a few other details that he throws in here, but he does come down to another interesting way of looking at the problem. Take any given thing in a plant and suggest that it could be done for say \$100,000 less.

Try looking at it this way. How much Framus Dioxide does the company have to sell to make the \$100,000 you might save? Well if it’s like most chemical products these days, Bigg would have to sell more than a million dollars’ worth. Okay? So what is the answer? How do you go about doing this “poor boy” plant?

Let’s start with our friend the consultant. As we talked about before, this is a little sidelight that I’m throwing in. He spent a lot of time talking with the people.

Now let’s go back to Mr. Carol. “About the time you familiarize yourself with the flow sheet of Framus plant, get off your well-padded chair, go out and look at the full-scale model, get to know the people and the product first-hand. It’s a continuous process. There is no law against dropping in during the night shift a few times. You’d be surprised what a problem a leaky valve can be at 2 a.m. on Sunday.”

He goes on to review the idea of thinking about the process in the very special ways that we all like to, and that comes back to making the decision: “Do I use a 3-inch line? Do I use a 4-inch line? What if we check the pressure-drop a little bit better? What’s the probability that the plant’s really going to have to expand? Maybe there are a few other things I could do that could change some individual parts of the plant by \$25,000? Four jobs like that and you’ve got your million dollar sale made.”

And that’s the end of the quotation for a while.

The basic thing is, yes, this also applies to all of us. There are plenty of places where we can look around the plant and decide whether something is really necessary or not.

Of course there are times that we must look around the plant, as we’ve discussed earlier, and be sure that we have included those things that are in fact necessary, because the last thing you want to do is spend 4 or 5 or 10 million dollars on a plant, only to find out that you have to spend another 10 million in order to make it safe enough to run, or to correct some problem that was developed initially; and now a product that was viable is now quite probably non-viable because of the doubling of the plant size, and the potential return is off but you now have a corporate commitment to it and it may be something that you have a contractual obligation to supply.

So all of these questions fit and are items to be concerned about as the problem continues developing.

Mr. Carol brings up the idea of what he calls “The Case of the Multiple Pumps,” and I’ll continue quoting from him: “This happened to me some years ago. The process called for 5 vacuum stills with float-controlled pumps on each receiver. The pumps were 10 horsepower, 316 stainless, and special low NPSH design, and thus represented a considerable investment.

“After some discussion with the production department representative we decided to install duplicate pumps for each receiver. Apparently the stills could be shut down for a maximum of only 30 minutes for pump repairs. This was obviously not long enough to repair a pump, even under ideal conditions.

“When I went over the flow sheet with the gentleman who was my boss he asked a few general questions and then said: ‘Very interesting, but which of your uncles is in the pump business?’

“I thereupon turned on my brightest look and stated: ‘But sir, the process is essentially continuous, and besides, the production man has a general rule that if a spare is required you might as well hook it up ready to go.’

“My boss then suggested that I improve my general knowledge of the situation with a couple of specific observations. There are a lot of essentially continuous processes that do not justify duplicate equipment if carefully designed. There are a lot of general rules that are poor substitutes for specific thinking.

“Well, you guessed it. I found a way to satisfy the production man: his maintenance problem on these pumps could be solved by one readily available uninstalled spare. When I added up the savings I really scared myself. The pumps were only the start. You know the rest – 5 starters, 5 services, 5 bases, 5 piping hookups, spare parts for the installed spares, and so on.

“When I reported this resolution of the problem to my boss you may rest assured that this produced some further pearls of wisdom. ‘Charlie, you have to understand the essential difference in the viewpoint of the production man and the design engineer. The production man is, and rightly so, primarily interested in a design that will operate with the least possible difficulty and interruption from maintenance, process upsets and other allied causes. Generally speaking the more you insure against these things, the higher the final cost of the installation. If you attempt to be a good guy and give the customer everything he wants without really convincing both him and yourself that each item is absolutely necessary, you are not really doing your job.’ ”

And this is true in many, many ways. Pumps are not the only things that often get spared as things go together. Additional pipelines are often put in when a relatively simple system of pigging out a pipeline, or cleaning it between uses, could allow it to be used for more than one product and save considerable problems in getting materials from one place to another.

A process that I was involved with one time required the use of sodium hydroxide. It had regularly been the procedure and the practice of the plant to use solid sodium hydroxide for several of their applications.

This material is somewhat delicate to handle, requiring some extra processes and treatments. It’s also somewhat difficult to store, since it’s hygroscopic, and this plant unfortunately happened to be in a high humidity area. So many of the questions of receiving, buying, delivering, worrying about dropping, the solid waste that was involved, on and on and on, suggested to me that it really wasn’t appropriate to continue using the solid material.

We looked into it and found that in their processing there was sufficient time for them to prepare ahead of time the concentration and the arrangement that they needed of the sodium hydroxide by taking a liquid material and heating it for a while and removing the water. This was also found out to be essentially the same cost difference for the increased price of the solid material.

In addition there was the question of what liquid bases should then be used?

Certainly the 70% would be most convenient to increase in concentration, but in looking at that, the 70% would have to be treated and prepared in the storage equipment to prevent freezing, and it would have to be maintained at an elevated temperature.

By using 50% the storage requirements were eliminated. The heating problem took just a little bit longer to remove a bit more water, but overall the savings to the process and the convenience to the operating department of not having to handle the solid sodium hydroxide made a considerable difference in the overall performance of the process, and everything that went along with it.

This saved them considerable capital money in handling conditions for feeding solid sodium hydroxide. Since they also had to have the 50% material for later processing in other portions of the same process the distribution change was minimal, but the capital changes were significant, and overall operating costs were essentially no different.

While material handling concerns such as the one I just discussed are typical for plant processes, one of the other things that is quite typical and is often overlooked is the idea of control, and how to achieve control during transfer.

I was very fortunate to have the experience of working with a group of people who had a very large process that needed both transfer of materials and control, and after looking at it for a while they made the decision to use variable-speed pumps to achieve the flow changes that they wanted, as well as to achieve the transfer of materials.

Later on I had the opportunity to work on a plant where there was a gas transfer between two processes. The gas was somewhat difficult to handle and there was relatively little pressure drop available between the two plants, but in looking at it, the idea from the prior use came to mind. I made a suggestion of it and found that we could in fact get a blower that would stand up to the corrosion conditions that we were looking at.

We could put a variable speed motor on it, measure the flow easily, and use that blower to effect both the gas transfer and achieve the control that we were looking for, while also helping to maintain slightly more stable plant conditions and reducing something they often found to be a difficulty for their plant, which was good serviceable control valves for a relatively corrosive material.

So the potential of extra maintenance, and significant maintenance, for a control valve was eliminated, while they still achieved good control and good plant performance.

Certainly in this case the idea of adding a variable speed pump might seem like an increase in cost, but when looking at the idea of the cost of a control valve, the cost of the operating equipment to effect the movement and the performance of that control valve, mounting that control valve in such a way that it could be easily maintained and operated, and providing other protections that went along with it, we now have a comparison of the somewhat significant additional requirements to install another valve, along with questions of possibly changing pipe sizes going in and out of the valve that would have required extra welding of fittings or extra preparations of fittings in one way or another – to the idea of a relatively simple change of just providing a variable speed controller for a motor.

Of course 30 to 50 years ago that kind of variable speed control was an expensive problem of itself, but today there is a significant variety of variable speed units that can be very simply added to or often included in motor control starters, which already had to be there in order to make the electric system operate for the driver system. So the controls were a very simple addition while helping to improve operations overall and reducing a potential maintenance problem.

Again our friend Mr. Carol puts it rather succinctly in discussing a particular situation. He suggests, and I quote: “For example, suppose you have to design a water pipeline 4,000 feet long to handle 1,000 gallons a minute against a given static head. After you calculate it out and add your usual J-factors for roughness etc you seem to have two logical choices: 10-inch pipe with a 100 horsepower pump, or 8-inch pipe with a 125 horsepower pump.

“After you estimate the installed cost of the two designs versus the projected operating cost you find that you’ll get an extra investment for the 10-inch pipe back in 4 ½ years. This is an expansion of a basic product the company will continue to make for a long time; therefore you suggest the installation of the 10-inch pipe and the 100 horsepower pump.

“Well, let’s look at this one from the Board of Director’s viewpoint. Say for instance that in the fiscal year in which your project came up the Board decided that they could allot 10 million dollars for capital expenditures. Say that they considered projects worth a total estimated aggregated cost of 30 million dollars. Naturally they could approve only one third of those presented.

“The projects they approved, assuming equal risk, were probably those with the shortest time to return the investment. You have therefore probably made a wrong decision. To put it another way, the Board has higher rate of return places it can invest the money you put into the pipeline.

“Maybe I can best illustrate this opus by a final quotation from our friend, the boss. He said, ‘Charlie, you may think this company is organized to make chemicals, or maybe even to make jobs for you and me. This is not so. This is not primarily a chemical plant; it is a dollar factory. It is organized to make money for the stockholders, and whatever you do here, don’t ever lose sight of this.’”

And of course I completely agree with that. Certainly there are altruistic reasons for many plants and for many products that are around, but ultimately our friend Mr. Peters, in his plant cost text book, started it off also with a picture that showed a plant with the equation under it that indicated that input + labor + a few dollars = output + a lot more dollars. And that’s something that we regularly have to keep in mind.

I continue now with an example about follow-up on making sure that something occurs, from an example that a friend of mine gave me a few years ago about a service station that was to be converted into other use. Because of this and the change-out of the service station, obviously there were vessels that had to be removed from the ground – the former gasoline storage vessels.

So these were taken out. They were taken to a storage area to determine whether there was some value in treating them, and they elected that there was not. The land was sold and arrangements were made for the vessels to be destroyed and taken care of. A contract was taken care of for that, and the seller had now completed all of his transactions. He had sold the land for the service station; he had sold off the tank and made arrangements for its destruction.

It seems that for some reason whoever took the responsibility for making sure that the tank was destroyed did not do it. So the tank lay in a field and ended up being sold 2 or 3 more times as part of the field, with no cognizance of what was to be done with this tank.

Lo and behold, some 15 years later there were some children playing in the field, and they decided that it would be fun to throw a firecracker into the gasoline tank. As you might suspect, there was just enough vapor in there that even after 15 years with the thing lying out in the field and going through everything, the tank exploded.

Well, with the documentation that there was on how many places and times that the tank had been sold and supposedly treated, you would think that there would be something in there that might be a division of responsibility, but no – it all ended up going back to the original owner of the tank, and he was judged responsible for everything.

So again, the litigiousness of our society is such that follow-up and completion on things must be taken care of. This is a horrible example of the problems that can come when some aspects of projects are not completed.

Now certainly we all know that there are punch lists when we get to the end of the project, and we very regularly go through those and make sure that they're taken care of with contractors, but this particular example leads us to the idea that there are things beyond the apparent punch list that are part of a project, that still must be documented and must be taken care of, and somewhere in the overall performance and treatment of the project these have to be considered and recognized in any of the planning and in any of the final reviews that go on with the project.

To continue with our look at the idea of what should be “In” and what should be “Out”: sometimes the idea of “In” and “Out” in a project is not just a small item such as those we've discussed, of a special way of packaging, or a particular pump, or whether or not additional pumps are required. Sometimes it gets a little bit larger.

Some few years ago there was a project around, that I was involved in that had a very interesting product, and had a very good economic condition on it. Without discussing exactly what was being made, there was approximately a 10 million dollar investment and the process gave a 20% return on investment, which was pretty good at the time.

The process had a waste stream that while undesirable was not really difficult to handle, but because of the volume and the character of the waste stream half of the investment, or 5 million dollars of the cost of the plant, was involved in treating this waste stream. A very simple treatment, but still, with this all in it was still an R.O.I. of 20%.

We began to look at this thing in detail and it was finally recognized that for that half of the plant involving the treatment of the waste stream, the R.O.I. was only about 5% versus contracting the disposal to others. This contracting was possible and was not a particularly big involvement, and we recognized that for considerable return on the whole plant, the waste treatment was going to cut into things, and if we only built the processing portion of the plant the R.O.I. was going to

run up into the 30 or 35% range, even though there was a waste. However, that could be handled as an operating cost.

So the final question came down to: were we better off to build the plant with the 35% R.O.I. on just the operating part, and contract the disposal of the waste stream, or to build the total plant as part of the base project and accept the 20% return, and be completely responsible for our own activities on-site?

These are not easy decisions to make, and that decision was obviously kicked on up and ultimately made, and without making a particular commitment one way or the other, the plant is still operating and doing well, and everything that goes along with it. But the decision of making that choice, as to whether the additional waste treatment facilities would be put in, was not something that was made at the engineering or the operating plant level. It was made some considerable distance above.

This often becomes a problem for those of us involved in project activities and project management, and we certainly don't like to be second guessed any more than anybody else does, regardless of which way the decision goes. Just the idea that it's going on is sometimes a little frustrating when we're putting together what we feel is a completely viable and fully appropriate plant design and then people begin to look at other reasons for doing or not doing portions of the plant.

For this reason we all have to recognize again that this is a team concept. We have one particular function, and that's to make the most effective use of the talents and resources that we have for any given system at any given time.

And continuing with an idea along this line we can go back to our friend Mr. Buchannan for an example. He included one in his article where he states: "The Case of the Cheap Dryer." And he continues to write:

"The viewpoints of the production supervisor and the maintenance engineer may sometimes differ but will frequently agree. This is particularly true where the continuity of operation is concerned. Both will ask: Is the proposed equipment suitable for the proposed service? Are the critical spares provided? Can maintenance be done without excessive production loss? Are proper maintenance facilities provided? Is there a space around the equipment to permit easy access for maintenance?"

"In a recent evaluation an engineer had the job of determining investment and operating costs for the manufacturing of a sheet product. This involved drying from an organic solvent. The engineer had considerable experience in the textile industry; he had recently made a thorough study of the costs of dyeing and subsequent drying of textiles. He therefore pulled from his files costs on a number of heated roll dryers, then interpolated between these costs the heat transfer that he estimated would be needed.

"This seemed reasonable enough until another engineer, who had been doing work in the paper industry, questioned why dryers for this sheet material should be markedly cheaper than paper

drying equipment. This led to a fair sized investigation, since the magnitude of the difference was approximately four-fold.

“The results showed that the cost of the drying equipment was a function of the permissible elongation of the material being dried. Since paper permits little elongation without tearing, elaborate speed control is required and rolls must be cast and machined rather than rolled and welded, as is permissible with textiles. Materials with intermediate properties will permit dryers with intermediate prices.

“Such scale-up from existing equipment is a valuable technique for pricing proposed equipment, but always take the viewpoint of the production supervisor and maintenance engineer. Be sure that the scale-up is based on equipment suitable for the proposed service – and I would include along with that the idea of recognizing what is suitable scale-up.

“In another project that was put in a number of years ago, a laboratory-type operation was very successfully done on manufacturing a product that was highly desirable and very profitable. The system was then to be scaled up.

“Well in the laboratory a small mixed tank was used for the preparation of material. Unfortunately, somewhere along the way the decision on scale-up was made by someone who was not particularly familiar with the whole concept, and instead of recognizing that the conditions of the fluid regime were important they made a scale-up strictly on the mechanical conditions, and therefore a laboratory piece of equipment that was turned at 40 r.p.m. turned out to be the criteria for the production vessel.

“So they tried to turn a vessel that was 1,000 times higher in volume at the same r.p.m., and when they did they got a material that was significantly finer and much more difficult to handle in all future processing; whereas if the fluid regime was maintained constant in equivalent Reynolds Numbers in the two vessels, the movement or the rotational speed of the paddle in the larger piece of equipment would probably have been more in the 18-20 r.p.m. range. The particle size would have been maintained, and further handling would have been less difficult.

“It ended up that with this very, very, fine material some additional considerable drying and handling problems had to be resolved, at considerable additional expense, and even though the scale-up engineer who was responsible initially was, unfortunately or fortunately, a PhD, his expertise did not cover the idea of scale-up.

“While he was responsible for the project and maintained that it had to be an exact mechanical match, continuous problems resulted from it, and there was no explaining or justifying or adjusting the requirement in order to resolve that problem. The vessel continued to run at the very high speed relative to its actual need, and the product was very, very, difficult to process and handle.”

Which of course again brings us back to the idea of: There must be confidence in the team members. There must be reasons to keep that confidence, and there must be a recognition that periodically, although a particular team member may seem more appropriate or more responsible

or more whatever in a given case, that it's not always necessarily the case. Certainly in this case it ended up being a very expensive item to continue to follow the lead on this particular team leader.

I mentioned earlier in our discussions an article by D.Q. Kern, an article called "Speculative Process Design." It was published in Chemical Engineering Magazine in October of 1959. I've always found it a worthwhile reference and hope that you will also find it so.

There are a number of categories in his article, and some very specific discussions. One of them we've already covered here initially, when we discussed and pointed out that there was a heat exchanger cleaning and operating problem which he solved by maintaining the flow of the fluids through the heat exchangers in order to prevent settling out and accumulated dirt. Of course this is a relatively simple trade-off for the rather expensive process of taking a heat exchanger out of service and putting it back in.

I would throw in at this point that there was another rather hefty heat exchanger design problem that I was involved in in the past, where the heat exchangers after installation certainly had very simple and straightforward operation, but we found that there was a continual corrosion problem. This was particularly discomfiting since these same style heat exchangers and generally the same characteristics of the heat exchanger were used in several other plants.

We went into a series of continuous modifications of the tubes in the heat exchangers, and this resulted in choosing to change from a standard steel tube to a copper-nickel tube for a period of time. Certainly performance and plant operability improved and we continued with it, but all the while continuing with our investigations.

It soon became evident to us that there was just a little bit of difference between the tubes that other plants were using and the ones that we were using, and that's that other plants were using a tube that was in fact drawn, whereas the tubes that we were using had been made up by rolling and welding sheet. The difference in the metallurgy of these two tubes was significant in terms of performance in our plant. When we changed over to the same tubes that every other plant used we began seeing the same service in steel tubes that they did, and of course that made it much more attractive for us to continue with the operation.

But returning to our friend Mr. Kern, his discussions in his article carry an awful lot of interesting comments on what can be done and how it can be done. He makes a suggestion early in his article that reverse thinking is essential, and I will quote from him from that article for a little bit, where he says:

"The first essential step in speculative approach may be called 'reverse thinking'. Consideration is not given to the small scale plant from which the data will evolve for the design of a large scale plant. Instead attention is directed toward the design of a large scale plant at the very outset of a project.

“Only those small scale experiments which can be used on the large scale are designed and carried out. In practice this produces many broad gaps which must be plugged, but it eliminates the preference for performing easier experiments rather than useful ones.

“The continuity of effort outlined here was born, admittedly, of hindsight. It originated from first-hand reviews of a number of experimental thermal research programs which declined from the pinnacle of hope to the threshold of abandonment. Some were abandoned because they never had anything to prove. A few of the many rescued projects are included in the concluding sections of this report, as illustrious examples.

“There are a number of useful empirical tools that facilitate the collection of the greatest amount of process plant design knowledge from a limited amount of experimentation. Recent articles in Chemical Engineering and texts have directed attention to similarity criteria. This is an excellent recommendation, but it concentrates attention on the act of correlation rather than the appraisal of the basic novelty of a physical or chemical system, or the need for the experiments and the competence of the design.”

Mr. Kern goes on with further details on how to select the methods of attack on particular problems, and we'll discuss a little bit of that later on, but one of the points that he brings out is the very early studies in similarity criteria. Making sure that the work that was done was appropriate to what was needed was done by Froude, after whom we name the Froude Number, and followed soon by Reynolds, after of course whom we name the Reynolds Number, and the development of other dimensionless numbers and analysis methods that have come in the time since then.

One of the things that popped up in my experiments and investigations in several areas was reviewed in an article that came in magazines close to the same time, thankfully for me, and that was that a cooling tower system did not seem to perform in the way that it should. In looking at that and doing some investigation I found out that our good friend the Froude Number was very importantly involved in that investigation.

It turned out that regardless of what you did and how you did it, in the downcomers from chilling, particularly surface or particularly direct condenser applications in cooling systems on evaporation systems, the Froude Number of the flow from those direct contact absorbers down into the well that fed the cooling water return to the towers, was a very significant item. If that number was just a little bit higher than it needed to be in order to get the water down it would quite often trap a bubble in the line, which would then be a reduction in flow capacity of the line, and that then would create obstructions and interruptions of the performance of the condenser and create quite a few difficulties in the water and fluid handling having to do with the whole of the condenser section.

By modifying either the diameter of the pipeline or the flow rates and the requirements into the system, you could avoid the idea of getting that bubble into the system and the potential fluctuations and surging that can come from doing that. This, very interestingly for me, came back to that investigating the Freud Number and making sure that the appropriate flow conditions existed.

That might be something that would be profitable for people to observe in many areas, because a second area where something like that occurred not long after that, again was another direct condensing application in a vacuum system where it was unfortunately found that a small bubble occurred in the dropleg from the condenser on the vacuum system, and that was significantly affecting the operation.

Fortunately in that case we were very easily able to locate that bubble; the drop pipeline was a fiberglass line that was translucent, and we could see the surging around a given area and the bubbles coming into the line. We were able to block that hole and settle down the vacuum condition and improve the operation very, very dramatically by that very simple little hole closure.

So again, things may not always be as difficult as they sometimes seem. Sometimes it may be a rather simple situation. Investigating the designs with the analysis tools that we find available in many areas can help a lot in solving both operating plant problems and avoiding problems during the design of plants. As usual the critical criteria is to get people together who know what they're willing to do and know what they really need to do, and who will discuss it intelligently with you and make final arrangements to do it in the proper and appropriate way.

This is not an easy function. In all projects every now and then you find a thorn that gives you a little bit of trouble, but we must keep looking and working for that under all conditions. We must be assured that we come up with the appropriate design, and that we come up with a design that not only will do the job that we need to be done, but that will do it efficiently and do it within the parameters of the operating requirements and the safety requirements, and of course the capital and budget requirements that we like to put on the projects.

As a further item in considering something like this, recognize that the construction people who are involved with your project may well be a very important and integral part of your team.

I can refer also to a situation where a plant decided that they needed a new vessel for some of their processing, and they decided that they would locate this vessel in a place where it seemed to be convenient to install it. But as the design developed and we started looking at the particular requirements, we finally recognized that in the area between where they wanted to put the vessel and the rest of the operating plant, there were locations for three potential other vessels for other products. If they put the first one into the most convenient place then the other three would almost be impossible to install, because they would be over buildings and over pipelines and over other existing vessels.

So the construction review at the time pointed out that if that vessel went in closest to the pipeline and we then walked out any other vessels, one after the other, going out to the easiest place to finally install, then the modifications of a few pipelines would end up being a lot easier to take care of than finding booms two or three times as long and with four and five times the lift capacity necessary to get into very intricate little corners of the operating plants and conditions.

At this point we will call it the end of Disk 2 Side 1 of the Professional Development Hour Course, “The Ins and Outs of Chemical Engineering,” and invite you to change to the next disk in the series of this training course. Thank you.

Tape 2 – Side 2 (Ins & Outs of Chemical Engineering, Disk 4 – Ed Hardin)

This is Disk 4, or Tape 2, Side 2, of the Professional Development Hour Course, “The Ins and Outs of Chemical Engineering” by Ed Hardin, a registered professional engineer in North Carolina, number 7449.

We’ve gone through a number of examples up to date of things that go into a project and why they could go in, and the manner in which the decisions are made for things to go into a project. Let’s emphasize a little bit now the idea about the Outs and what we can look for there, but let’s do a bit of review first of the ideas that are important to the whole process.

Certainly the basic idea is a good clean process to achieve the desired product or goal of what we’re looking to. This usually involves the collaboration and participation of a number of people, and it can include everything from research chemists and their developments to vendors as they bring ideas into a plant and offer suggestions on how to improve conditions. And of course it involves the management, it involves the plant operations people, it involves maintenance people, and it involves the planning people and anybody who’s going to be involved in making up the project definition and development, and the estimate that will ultimately be a primary tool in making a decision as to whether or not something should be done.

As we consider all of these areas, one of the things that was brought out before was that everybody has a right to his opinion as they go into these things, and yes, that’s very true; but one of the things that has to get recognized is that sometimes an opinion is in direct opposition to the facts, or to science, or to practicality, or to a number of other things, and there has to be a reasonable way to recognize this and discuss it and review it with the person who makes the suggestion, and come to a general agreement.

A very specific example that was given a little earlier was the idea of the selection of a dryer. One person involved in the project made his decision on what the dryer should be for a web kind of arrangement on the basis of cloth handling systems, whereas another fellow who was part of the system recognized that there was a whole different kind of drying problem, and that was the drying of paper. They discussed it and came up with the idea that it was the matter of the extensibility of the material and the sensitivity of that extensible nature of the material that was a primary control on the cost, particularly of the overall control system, in producing the desired web product.

That’s the kind of thing that we all need to involve ourselves in as we look forward to projects. Certainly we discussed earlier also the idea of pumps, and do we really need installed spare pumps when we recognize that that involves an additional base, an additional motor starter, an additional service supply, multiple additional valves in order to be able to parallel the inlets and

outlets and crossovers and a few other things for the pumps, and to allow for maintenance requirements on the pump.

Certainly from the standpoint of pumps another thing that needs to be recognized is that it's quite often necessary to have additional pumping capacity in a given situation, and often an additional pump is requested. So we go out and we look for a similar pump, and we look for the various costs and we find out that while we have pumps made by Manufacturer Q, there is another pump manufacturer that has come online and is offering a variety of pump that is very similar in nature.

This new manufacturer, Manufacturer M, says sure, we can put these pumps in parallel and operate them together; but if you look at the pump curves you find that there's a considerable difference in slope in a portion of the curve.

A little bit of experience will point out to you that if you try to use those pumps in parallel there's going to be some hunting and moving back and forth, and quite often you're going to end up with less capacity than you really want overall simply because neither one of the pumps will work at the desired condition when they are working together. One will create a different kind of flow regime at the outlet generally than the other one will, and will change the whole nature of the flow conditions.

Another thing that can get involved with looking at, say, particularly a pump, but it certainly applies to a number of other things, where you can look and find that again a new manufacturer, a new supplier, will supply a very similar pump for a lower cost. Well, it's easy to make that decision, but I would review with you for a moment a case in which I was involved where the pumps were rather substantial in size.

The savings in putting the newer pump in was probably in the neighborhood of \$500 to \$700 per pump for a particular application, and that's not something to be sneezed at. However when you looked at it, since this was only going to be one application in the plant, there was about \$4,000 in spare parts that was going to be required for this particular set of pumps. If we used the matching pumps, although we'd pay \$700 or \$800 more initially, we would not have to buy that additional \$4,000 to \$5,000 in spare parts.

So this is where one of the overall evaluations of a project, particularly a modification of an existing plant, must involve a variety of people, and for a variety of reasons. Both of these are somewhat examples of the discussion that we started off with, of the idea of Outs and being able to make a specific comment or review with someone about why something should not be part of a project, or the project should be done in different way than what someone might suggest.

As a parallel example, or a further example of a condition such as this: Quite often a project is rather fully developed and looks very promising, or is necessary for various practical reasons, and it becomes approved – and I would suggest that often these kinds of projects are in the environmental or safety area. People then go and they begin to see about the installation.

In cases like this all of the planning, all of the good work and so on, may not necessarily recognize what's going to be required in the field. In one particular case that I was involved in

quite a bit of time ago we did get down to that situation of having the project ready to go into the field, and a final review and discussion pointed out that the capital cost that was assigned was wonderful and very good for the project as planned and as designed, but that because of conditions in the plant, particularly soil conditions, the particular vessels and plans that they had made for this plant could not be realized within the capital cost that was suggested.

So a very quick changeover had to be found, and we were very fortunate that there were people who were part of the project who made suggestions that could realize the effective change of the processing methods, utilize a great deal of the project as it was designed, but remove and take out those areas that were not going to be suitable for the soil conditions of the plant, and move the project forward.

This same thing happened on another occasion that I was made aware of. Fortunately or unfortunately I was not part of the project, but some processing that required some very heavy equipment was initiated. Land was purchased for the project and the equipment was purchased.

They were already starting to work in the field and to do foundation development work for the project when they all of a sudden realized that, again, soil conditions were going to make necessary the development of a considerable pile system in order to support these very heavy pieces of equipment in an untenable area. As a result of this the project was delayed by some year, approximately, when people recognized that the cost of the piling system was just not feasible and not realistic, and the whole plant had to be re-sited.

A lot of equipment that had already been purchased and already committed then had to be stored and held for a period of a year or more while the new site was developed and prepared and the plant was reconstructed there. This is not only an expensive thing to do – certainly not as expensive as placing the plant in the wrong area and fighting that problem, but it is expensive and it's embarrassing to everyone involved.

Now many of the points that we've discussed here might be criticized as not necessarily being the Ins and Outs of chemical engineering. However, everything in a project becomes a responsibility for a lot of people, so we all have some of the responsibility for recognizing where projects go and how they are developed. In most cases I think I'm probably talking to chemical engineers who are involved in project development. As project managers and project leaders, these peripheral areas are also of some concern to you, because ultimately it will be your responsibility to assure the correct development of the whole project.

Certainly we rely on our friends in the other aspects of the profession to be able to review the things that we have going on and to be able to understand what we're doing. It comes back to the idea of the project manager and all of the people involved being able to recognize and suggest and offer opinions, and offer discussion points and ideas on how all of the pieces are going to come together: what their relative size is, what the importance is...

We mentioned before the idea of packaging, that some people decided that tank car shipping was going to be their method of distribution when really the product needed to go into aerosol cans –

certainly a major difference of opinion that should have been aired and directed earlier in the project.

The concepts of environmental control, environmental treatment, waste management, waste control and waste treatment in projects, as we have reviewed before, have become very, very important. Again, one of the things that needs to be recognized is the idea of: Is that something that should be part of the project – we kind of discussed this in a vignette a little earlier – or is it something that should be contracted? Here again, some involvement with people outside the corporation may be necessary on this.

Materials of construction are certainly an area that can have a significant impact on projects. Whether items are made out of carbon steel or stainless steel, or whether they require glass lining, or whether they can be done in the various types of polymer containers; whether they're fiber glass and lined in some way, or sometimes the rotationally cast vessels – all give us opportunities to look at and investigate methods of treatment.

One of the things that might be appropriate to do in any given project is to start looking at history in a given process, and see whether there's anything there that might recommend itself even today as it did long, long ago in projects.

I was rather amazed on one occasion to find an idea of tankage, a rather large tankage that generally can be very expensive in a number of ways. Some people had developed a method of using concrete blocks with some reinforcing in the blocks, and putting supporting hoops around the tanks to carry the major hoop stress. By holding the blocks together in this way and hooping them they were able to get very effective large volume storage for a relatively low cost.

Now this may not be appropriate in all areas, but the technology for looking into doing that and the success that these particular people had in doing it goes back to the use of wood stave tanks from long ago, where quite often tanks were made out of vertical wood staves that were put together and held in by clamp hoops that were wrapped around and bolted together to create the sealing conditions between the units.

It's very much like building a barrel, but without the fattened portion of the barrel, and very large tanks like this were used for many, many years in the mining industry. They were handling some very unusual materials, and by using wood they had something that would stand up to many physically rough conditions as well as some chemically difficult conditions, still allow for easy repair and replacement periodically, and allow for a good long life.

Another area of interest when dealing with particularly chemical projects that should bear some consideration is the idea of how much inventory needs to be held of a given product. In many cases we like to have an intermediate hold capability, to allow for the various changes in plant conditions, but when the materials that are being held have very serious health or explosion or cost or any of the other conditions that go along that line, it may be appropriate to look for ways to minimize the inventory – for instance by changing to a continuous process rather than a semi-batch process, or by finding a better way to generate the material as needed instead of bringing in large quantities of the material and storing them.

All of these things, again, come down to being a responsibility not only of the project manager, but of everyone related to the project. So the idea that someone comes in and says, “Gee, I really need to have X many gallons or tons of storage of a given material,” is an interesting opinion but not necessarily a specific requirement of the project. While quite often things like that get forced into projects, they’re the kind of things that should be looked at and reviewed and discussed from a team concept to find out whether it really is appropriate to keep so much of this particular material or chemical in the plant at any given time, and run all of the various safety questions and control questions of processing those materials.

Conversely it’s also appropriate to look particularly at energy supplies to a plant process, and consider whether alternatives need to be there. In simple areas certainly you can be easily covered – where you have a large plant and you need some steam and there’s a large boiler available, and so on.

However in certain situations, particularly in more moderate sized plants or in specialty processing applications, it may be appropriate to have a boiler that has both gas and oil capacity and capabilities, to be sure in various curtailment or operating conditions that the necessary energy can still be available for safe operation, particularly safe shut-down in certain conditions, of the plant.

The same things holds very true with electrical requirements. It is becoming more and more popular to have on-site the generating capability, to some extent, to handle emergency operations for various processes. We quite regularly see and hear particularly of nuclear power plants that if their diesel generator is down the N.R.C. requires that the whole plant be shut down until that diesel generator is brought back into operation.

Where specialty gases or particularly hazardous gases are handled it is usually very appropriate to have a generator available to take care of certain mixing functions, or certain storage or cooling functions or transfer functions, for the hazardous materials, to be sure that they are not allowed to develop into a condition where it could be a danger to the personnel, the plant, or the surrounding area.

Another very important “Out” concept to consider in process development and project development for processes is the idea of how to get material out of the vessels. There are a number of reasons why things like that would need to be done, not the least of which is probably the most important one, and that’s the idea of sampling for quality control.

The idea of transferring from one vessel to another certainly would obviously be considered the first need of the project, but to be able to get reasonable samples at reasonable times during the process and under safe conditions so that those samples can be quickly gotten to a laboratory, or providing a process situation with in-line or in-process sampling and testing methods to know the quality of the materials that are being handled is a very important concept to consider in getting materials out.

Under other conditions the idea of emergency methods for getting material out is something that needs also to be considered in the project. Is it necessary under any condition to have an emergency dump capability? The old idea of rupture disks is being looked at as being rather passé now, because of the potential environmental discharge problems.

There may be some conditions where a collection tank or a recovery tank for materials discharge is a worthwhile addition to a project from an equipment protection standpoint, as well as from an overall plant and personnel safety standpoint.

Instrumentation and controls on plant processes are often areas where people like to have redundant capabilities. Safety limits are certainly required. High safety limits are often needed too. High-high safety limits? Now we're starting getting into the idea of: how much redundancy is appropriate? And the same thing when we go back to lows, and low-lows, and low-low-lows.

So in many of those cases maybe one of the things that should be looked at is: is there a better way to handle the material into the vessel, to make sure that no particular pressure can be achieved by the feed conditions coming into the system so that the vessel does not have to have two and three and four levels of protection in order to be able to be assured that it's safe and in condition?

Another thing to consider when looking at processing systems with the potential question: "Should it be out?" is any of the particular gases that are part of the system, and whether they should be removed during the processing. A number of materials that I've been privileged to help with have had the condition that a little bit of oxygen will often cause a reaction of a byproduct that creates a discoloration. The actual blanketing and elimination of oxygen to as great an extent as possible from the system was valuable in reducing the amount of processing that was required for later purification and recovery in order to have a more highly valued product, and a product that could command a better price.

As you develop your systems you may find that other gases fall into that same area. It always used to be a little bit of a fascination to me from a long time ago to look at the Orsat analysis method that was used on boiler gases, and recognize that carbon monoxide, carbon dioxide, oxygen, nitrogen, could all be very simply removed in sequence with some minor chemicals in a test apparatus.

Certainly instrumentation today makes a lot of that inappropriate, but the concepts that are involved, of finding some way that would remove a particular problem gas or a particular problem material from the vessel might be a very worthwhile consideration in any given project.

Solid materials fall into that same kind of category. Certainly cases where the emission of a gas might have an effect on the kinetics or the equilibrium point of a given process: if that gas can be removed and removed effectively, or if the vapor area of the vessel can be transferred out of the vessel, processed for the removal of undesirable materials with the rest of the material recycled into the vessel – considerations like that can be of significant importance to project development.

In our discussions so far we've emphasized and concentrated a great deal on the project management and the project design and the project development of items and changes for plants. Another area that probably bears some consideration for all of us is to look at the idea of ourselves as Ins and Outs, and recognize that there are certain things that are appropriate as Ins and Outs for chemical engineers as well as chemical engineering.

This applies to people in a lot of other fields, too, in that it is always our responsibility to keep up with moving trends. We have a variety of methods of doing that today; certainly magazines and organs of the professional societies help a great deal in providing new information. We must be very critical in some of these situations to recognize that not every new article introduces a new idea – often it's a re-hashing of an old idea, sometimes with benefit, sometimes with error.

So in looking particularly at periodicals and magazines from professional societies, be sure to also read the letters to the editor. The comments that come in there quite often point out that certain things that were suggested in various articles don't necessarily fit the conditions today, for reasons that people have forgotten about from the past.

Certainly the internet provides us with an opportunity to do a lot of investigation of what is done and how it's done, and we should regularly use situations like that. Look around also and don't hesitate to go to meetings of other professional societies. Talk particularly with your fellow professionals in other fields about certain things that are occurring in their field, so that you can stay a bit aware of the new things that are coming on and how they're handled, and where there might be benefits to you in construction techniques, or in materials, or in recognizing warning signs or understanding the requirements for any of the processing conditions – particularly environmental conditions or atmospheric conditions that might have effects on your plant and your plant projects.

I was particularly impressed with the idea of recognizing that people from varying backgrounds can offer significant gains in certain situations by a fellow who worked for me some time ago as a laborer in an operating plant. He was ambitious enough that he was going to evening college and he ultimately got a degree in Business Management and went out looking for another job, somewhat later in life you might suggest – I think he was well into his 30s. He was selected by a relatively large manufacturing company to be part of their personnel and administrative section of the plant.

This particular plant came up with a change that they were looking to do in the plant, which was going to have a serious effect on and involvement of all of the working personnel in the plant. So the corporate personnel group sat down and made various plans on how to introduce this new idea, what they would say and how they would offer it, and the conditions that were to be changed and how they would explain it. They had a rather thorough program developed for achieving this goal.

This was about the time that my friend became part of the organization, and as a final review he was invited to sit in on a meeting – they did one last review on this before they were to start it within a week or so.

They asked him his opinion on it, and he proceeded to offer a very reasoned opinion from the standpoint of the men on the floor. He suggested that there were a number of areas where their opinions and their beliefs of what were going to be the attitudes of the working people were in error, and probably were not going to be recognized in that way in the plant; that it would cause certain difficulties and that those difficulties would then add to other problems later on, and so on and so on.

Well they said, "Gee, that's very interesting, but you know, we've been at this a long time and so we're going to go ahead with our plan," which they did.

Unfortunately almost everything worked out in the way that my friend had suggested, so after a month or so of trying this new implementation they went back, stopped it completely, redid their whole program and began a whole new way of introducing this into the plant that recognized more of the conditions of the people on the floor and how they thought about things. They were able to bring it in, and with the new implementation method they were successful in introducing the changes and improving overall conditions in the plant.

The point that I want to emphasize here is that just because someone brings an idea to the table – and again, we're back to the team concept of recognizing that everybody is part of what's going on and needs to be given the opportunity to have appropriate input into the project – that oftentimes when something doesn't seem particularly reasonable at the time, maybe it needs a little more investigation. Maybe it doesn't. It's a very delicate line that has to be observed in all of this to recognize whose ideas should be included, whose ideas should not be included, and why.

So it becomes appropriate to look into other areas, to listen to other people, to understand that they're offering and trying to find the best way to do the job that everybody's trying to get finished, and they want to get it done in an effective and efficient way so that it benefits the company.

I won't say that that's true on all occasions and at all times, but my general experience is that for something in the 95% range, it's true. As with all of us I have run into those people who seem to object just for the purpose of objecting and offering the counter argument just for the purpose of delaying things. One of the things that we all have to recognize is that it's much easier to say, "No, that's not going to work!" than to be able to come later and say, "Well gee, you know, you guys found a way to do it!" or especially to go out on a limb and say, "Yes, I believe it should be done this way," and then have to prove that it will work in fact in that way.

As a little sideline on that I have a running discussion with a friend of mine about the idea of trisecting an angle. We all have heard many times in plane geometry and in other areas, and we may even have looked at it rather significantly from a higher mathematics standpoint, and we have all been told, "No, that's something that absolutely cannot be done with straight edge and compass, because there are various mathematical conditions that cannot be addressed in that way."

The argument goes that there have probably been a lot of things that have occurred like that in time, and lo and behold somebody who didn't know about all those limitations came up with a way of solving whatever the problem is and bypassing the limitations that everyone else put on themselves.

So we jokingly look at each other when we think we've run into a condition like that, and we say, "Well sure, if you're going to do it *that* way!" – and recognize that we do have to keep our minds open and we have to keep our attitudes open to look in a variety of sources for the appropriate way to solve problems.

As we approach the end of this disk in a few minutes, I would like to go back again for just a little bit to review some of the things that are involved and some of the suggestions that I'm making here. I very definitely recommend that you look at the materials, the articles that I've included with this to offer some insights into how to think and consider projects and various areas of projects for development. Some of them might seem a little dated to some of the younger engineers, but I think that just like $2 + 2$ is still 4, there are some ideas in the past that are still valid and worth considering.

Again, I recommend and suggest that you keep going over those kinds of things with new publications and new ways of reading and looking at things. Personally I recently picked up a book called "God's Equation," which was a discussion of how we have moved through time from the basic physics that was thought of long ago, to Newton with gravity, and then the addition of Quantum Physics and a number of other varieties. They pointed out that people finally came to a place where they recognized that they needed to work with non-Euclidian geometry and with curved space in order to be able to achieve certain objectives. They worked and worked and worked with that, and lo and behold at the end of this book they now say, "Well, that was an interesting bypass for a while, but really it can all be addressed with the basic geometry that we knew from long ago."

Now, again, that's not something that's always going to occur in all conditions, but it is something to be aware of and to consider, and certainly we in chemical engineering, with the variety of investigation methods that we use and with the special effects of physical chemistry and the various equations that are developed from there – we do need to look and consider what we're using and why we're using it.

I'm afraid that there's another area that I feel very strongly about, and that is many of the software applications that are being developed and provided now. Certainly the experience that is included in many of these software applications is very useful for a lot of things that are going on, but as we move into different or newer areas one of the things that we have to recognize is: The software and its method of development is always going to be biased by the understanding and the knowledge of those who write it, and those who consider it and plan its development, so that the choice of the calculation methods or the choice of the equations to be used may have always been good for the conditions under which they are using them, but they may not necessarily always be good for all other conditions.

I particularly remember reading a few years ago about equations of state that fall particularly in that area. Equations of state that are very good and very workable at normal atmospheric conditions are not necessarily the best to use in high vacuum conditions, or in high pressure conditions, or in high temperatures. So a variation, or a new or different equation of state, might be appropriate there.

The same kind of thing is true when we come to data itself, and data projection. One of the things that we always love to do is to straight-line project data. It doesn't always work. Keep that in mind. Straight-line projections are wonderful in close proximity or near the particular area of use, but once you move away from that a bit it can be a bit confusing.

To this extent I would recommend that you consider a chapter in the booklet by Wei, Russell and Swartzlander, a book called "The Structure of the Chemical Process Industries," where they discuss matrices as applied to general economic theory.

The point that they make in there is that often those things that are easily projected initially in looking at straight-line projections or even matrix projections that are involved, once you get into using something two or three times the effect often changes, and some of the byproducts or other materials come back and change the conditions.

We all saw this quite regularly when we studied kinetics and saw the effects of byproducts and intermediate products on process kinetics, and considered how those things might be removed. We now have the condition that this can also exist in a number of other areas, and we need to keep that in mind – for ourselves, but certainly for projects, for project development, and for everything having to do with chemical processing. We need to be sure that we put into the chemical processes those things that belong in, and that we keep out those things that will not help us and that may end up doing some harm, not only to the process, but to the individuals and people dealing with it.

With this we're almost at the end of the disk, and so I thank you for your interest in this course. I wish you good fortune in the quiz that will be related to it, and this will be the end of Disk 4, or Tape 2 Side 2, of the Professional Development Hour Course, "The Ins and Outs of Chemical Engineering" by Ed Hardin. Thank you.