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THE INDUSTRIAL COLLEGE OF THE ARMED FORCES

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RESTRICTED

GAGES

15 March 1949

COLONEL HENRY: Gentlemen, in the study of production we are constantly reminded of the importance of mass production at low cost. In attaining this goal, however, many factors must be taken into consideration, a few of which are interchangeability, spoilage, and maintenance of proper standards of quality and operational performance.

Inspection and, in particular, the use of gages and precision-measuring equipment is a means of securing these qualities. Machine-made articles are only approximately identical and uniform. Nobody and no machine can make two things exactly alike. The difference may be scarcely measurable but it will be there nevertheless. Occasionally, these minor changes bunch together and the product suddenly deviates sharply from specifications. In recent years two very important advancements have added considerably in controlling these deviations, namely, statistical quality control and the use of gages and precision-measuring equipment.

Our speaker today is especially well qualified to talk on this subject. He has had many years of experience in devising, planning and carrying out essential inspection, quality control, and gaging programs and is at present Quality Control Engineer with the Federal Products Corporation.

I take great pleasure in introducing Mr. Clifford W. Kennedy, who will speak to you on the subject of "Gages". Mr. Kennedy.

MR. KENNEDY: Thank you, Colonel.

If you don't mind, I am going right ahead informally. Let's not call this a speech. I have some notes here but they are simply to hold me within the time limit. I also have them so I won't forget something. I am going to be very elementary in what I have to say.

Speaking of products, I must throw this in right off the bat: There is no intention here today, gentlemen, of a commercial plug, although it looks like it (referring to the items on display). I am trying as best I can to represent the gaging industry. Naturally, I have available literature of the kind you received and I have some apparatus. Others make it. Don't think this is Jack Benny, for Luckies, or something of that nature.

Aiming for the target of this discussion, there are a few diverse or relevant points that perhaps should be taken up before we get down to pulling the rabbit out of the hat. It is like an artist painting a picture. There is always the background that he paints.

In the first place, measurement is a very common human activity. It is probably the most common activity we have. Time is one of the most common forms of measurement. You might say, "How far is it to Baltimore?" You never get into your car but what distance counts. Subconsciously you measure the height of a step before you take it. Either that or you fall flat on your face. Then, too, sometimes late at night and perhaps early in the morning we are unable to measure accurately. When you park your car, you sidle up and back in. You have to measure the distance. Then you look at the parking meter to measure the time. It just goes on all day long from the minute you get up. Historically, measurement started when prehistoric man said, "I want another one like that." The minute you want some form of duplication, you must have some form of measurement.

I do not know which came first, the hen or the egg; I have never found out. I am not certain, in regard to industrial progress, whether measurement preceded progress or came afterward. But one thing is absolutely certain: As we have made industrial progress, the ability to measure better has tied right in with it like a Siamese twin. Presently, I would say the race is a tie. We are developing in measurement an ability to measure readily to a millionth part of an inch and, if you want, to billionths of an inch. So far as I am concerned, production people talk about it but they are not ready to go yet to a millionth of an inch. So, generally speaking, we are a step or two ahead.

I might bring this question of measurement out of history. There was a time, in the days of King Henry, when the unit of measurement, or distance, was from one's nose to the end of his finger tips. That was the yard. They took sixteen fellows and stood them foot to foot. That made the rod. I suppose from that also came the "foot."

I was reading just last night that in Switzerland, 'way back, they measured property by having a man go to the roof of his house or barn and throw out a scythe or sickle. Wherever it landed and stuck that was as far as his chickens could travel. If the chickens went beyond that point, they belonged to his neighbor. That was the way they measured in Switzerland.

Out of the old Anglo-Saxon came the term "uncia," which was their word for thumbnail. "Uncia" has become the inch in the English system.

Then we have the barleycorn. That was a form of measurement, no less. It is still used in the shoe industry for making certain measurements.

The French and some of the other Europeans were a little wiser. They took the circumference of the earth, divided it by thirty million, or some such partition as that, and got meters. Then they were wise enough to divide the meters into a hundred parts and got the centimeter. They divided that still further into ten parts and got the millimeter. They multiplied the meter by a thousand and got the kilometer. We, with our English heritage, know similar divisions as inch, foot, and yard.

From your point of view, probably the most interesting history is that of Eli Whitney, who found an arrangement for having one man make one part of a musket and another man make another part of the musket. Then finally a fifth or sixth man put them together. The Revolutionary War soldiers were very fond of those muskets because when they broke one of their own all they had to do was take a musket off a dead man, extract the part they needed, put it on and everything was all right. Interchangeability started then. Mass production started then.

Whitney discovered he had to have some gages so that the men would make parts of a certain size, and make them interchangeable. Industry copied Whitney's mass-production idea. They also copied his gages. But, to a considerable degree, those are still unchanged. The Revolutionary War gages were no better than the one that Eli Whitney devised. When you walk through the most modern plant today you still see that type of gaging. Yet, there are so many better types that can be had. I will demonstrate that in a minute.

Let us bring this historical business home. I was at the Watervliet Arsenal a short while ago. If you ever visit there you will see a glass case containing something that looks like tennis rackets. Those, gentlemen, are gages to be used in measuring cannonballs. We have a letter dated 1862 indicating that the Arsenal at that time wanted two thousand of the ten-inch size. They were to be held to between 9.84 and 9.9 inches. These were the gages that were to be used. They were just wooden-frame pieces with holes in them.

If you go down to the Frankford Arsenal, which is very modern, you will still see some little pieces of steel with holes bored in them. In almost a hundred years now, there has been no change. However, they are getting a little better. Perhaps that is one of the reasons I am here this morning.

I go into some of these modern plants and see their ultra-modern reception rooms, parquet floors, conveyers, the latest in automatic machinery, everything right up to the minute out to the shipping door.

I was in a plant a short while ago where they didn't have a window. Even the air was controlled. I don't know but what their thinking was controlled also. But they had some of this traditional gaging stuff out on their machines. It made me think of getting into a 1949 Cadillac, driving up in a duster, cap, goggles, and things of that nature. It is sort of an anachronism.

I used to own a Reo car that would do fifty miles an hour. It lasted fifty thousand miles. If I buy a car today it must be good for a hundred miles an hour. It must last at least a hundred thousand miles. In the days of my Reo, a two-thousandths tolerance was a wonderful thing, they thought. Today, two-tenths is big.

I was in a plant in Indiana a short while ago where they were grinding diesel crankshafts, or attempting to do so. They were holding them to a fifteen millionth tolerance. The difference is wear. In order to manufacture to that precision, gages had to be able to measure better.

Now I know of a textile concern in New England of which it is said every once in awhile, "Is that shop up there still letting the paint run into the holes in order to get a better fit?" You cannot manufacture that way!

In the industrial picture during the war, you, or others like you, were responsible for a lot of our trouble. The magazines throughout the country were given the story of the Norden bombsight. You glamorized pin-point bombing. Because of the fact that these things were made in mass production at tolerances of a tenth, what happened? The fellow who was buying a pencil would pick it up, pay the clerk, walk out of the store and not think much about it. Even you today, if you buy a pencil like this (indicating), would pick it up and probably look in it to observe the workmanship of the thing. The public is now in the habit of looking for precision. From the commercial angle, that affects us a great deal, both in measuring and in manufacturing.

Now the modern way, apparently, of working up a job is to engineer it. The product is designed. Not only is the product designed but the process, the type of machine to be used is selected; also the type of tooling. The method of handling the goods, the conveyer system, the lighting--everything is planned, ordered. The plant, or the section of the plant, that is going to make this little part is set up. Small pilot lots are started along. The operator has been trained. Even the time and methods boys have gotten out their stop watches and have set a standard or an incentive. Out dribble the first few pieces. Then somebody stops the thing. They aren't exactly right. So they consult the blueprints. Then they commence to look around for something with which

to measure. In the average plant, "something to measure with" is usually this (indicating). It is as common as the air that you breathe. All you have to do in the ordinary shop is just look around for a micrometer, or something.

In the early part of the war I was in the Denver ordnance plant under an exactly similar situation. One day we had to walk nearly a mile (the length of that plant) over to the tool shop to find a pair of micrometers. Those fellows out there just naturally didn't have them. You run into that situation even today, not having it right at hand just at the minute you need it in order to measure results adequately.

Most of the more modern products are very intricate in design. Now will that give you the answer you need? Is it right? Does it match the blueprint? An instrument like the micrometer may not be sufficient or adequate. Some products are so intricate you need a special form of gage immediately in order to check them.

What I am trying to suggest out of that story is that when a product is designed, when the process, the machining, and everything is worked out, right then is the time to design the gaging materials to be used; the methods that are to be used to check the conformance of that product to the specifications. Inspectors and gage engineers can read blueprints. We do not have to wait until you have made a part. We can design the gage. We can cocoon the gage and put it aside until you are ready for it. That is one thing that I would like to throw heavily into the minds of some of you. I hope some day it will come out of the files when you have some industrial problem to solve.

My next point is that you plan your gages for the operator and not for the inspector, the engineer, or anybody else. In any industrial plant, gentlemen, or any industrial company, there are only two men who count: One is the operator who makes the stuff, and the other is the salesman who sells it. Everybody else in that plant is either a service to one or the other of those two, or else he is a parasite.

So, in planning your gages, plan the outfit for the operator. Work it so that he can see what he is doing. Make the others use it. In our plant at Providence, just to give you an example, or in the plant where I was in Denver, the gaging outfit was designed for the operator. He had it on his bench. If the inspector wanted to know something about the product, he came and used the operator's layout. He did not have something special.

I was in a plant in Buffalo where they were making some steering knuckle bolts. It was a grinding process. The fellows at the machines were equipped with "mikes." After they made a thousand or so a day, a tote box was taken down to an inspector's crib, perhaps a quarter of a mile away, and there the inspectors, equipped with these electrical

instruments, would make measurements in millionths. Now I don't know whether you have ever seen an inspector working with an electrical gage, but he can actually measure a zephyr. Well, along about three or four days later, back to the operators of the machines would come a report to the effect that on such and such a day there was 8 percent scrap, or something like that.

So what did we do in that plant? We made arrangements--we rigged it up with the union, the time department, and everything else--whereby that operator, any time he could make one piece that in his opinion was perfect, could go down and use that electrical gage. When he was satisfied he had a piece that was right on the mean then we supplied him with a little indicating gage. He set that gage to that piece. He zeroed it to those parts. From then on as he ground pieces he snapped the gage on the pieces he made.

Do you get the psychology of that, gentlemen? He was responsible from start to finish. He made his own master. He set his own gage.

One hundred percent inspection is the bunk. I used to say 100 per cent inspection was about 80 percent accurate. I have now revised that figure, after making a study of airplane engine factories in Connecticut, to 68 percent. If you have a hundred pieces among ten thousand that are out of tolerance, and you turn those ten thousand pieces over to an inspector, the inspector will probably catch sixty-eight of the hundred pieces. The other thirty-two will get by. If you have the lot reinspected of those thirty-two they will get about 54 percent. That's fifteen pieces. Then if you again have the remainder reinspected, they will get something like 34 percent, and so on. The thing never reaches zero no matter how many times it is inspected.

It is better to prevent than it is to correct. Your only solution is to make them right, and the only man who can make them right is the operator. But he needs the equipment to see what he has done.

Here is another commercial or industrial policy. In a shop where they are boring, they have a little toolroom plug gage. They shove it in the hole to see if it fits or not. That costs about $10, maybe $5. You have ten machines using $50 or $100 worth of traditional gages. So we go in with one of our small-bore gages. We'll show it to them. They'll say, "Oh, no; we can't afford that." But the old traditional gage is costing them money, gentlemen. If they put in the new gage, they will make money by the reduction and prevention of scrap and rework. We have been able to prove that point over and over again. In other words, our statement is that if a gage doesn't pay for itself in a period from six months to a year, or less, don't buy it. The only place where price is a consideration is in the competitive situation, where for the same

equipments somebody will have a lower price than somebody else. But don't say, and don't think, that the gage costs anything. It begins to cost when it does you no good.

Coming back to this: They have been using the old traditional gage in this particular operation and their scrap and rework is sometimes 5, 10, or 15 percent. They put the new gage in the hands of an operator and scrap goes down to three, two and one percent. For each of the traditional gages they made they might as well have tossed the $5 out the window. They did nothing. They made no change in the situation.

(Mr. Kennedy proceeded to the blackboard.)

Here is a little piece of economics that you may be interested in--I hope. In this particular plant, the cost department had numerous breaking points where it got the inventory value of the goods produced every week. This study happened to be taken from a screw-machine department. In that week it produced $14,000 worth of items in that condition. That included the overhead and everything else. The cost department officials arranged also to get the value, in dollars, of the scrap made that week on the rework operations or salvage operations. They charged up the value of any equipment bought in that department in order to secure conformance, like gages, new chucks, new tools--anything that was designed to make a better product. Incidentally, they amortized that figure on a 25-week basis. They also got the inspection pay roll and all of that added up to a total. They ratioed that total in dollars against the goods made. At the time this thing started, that ratio was sixteen cents. A few weeks later it was nine cents. Six weeks later it had gone down to six cents. The last time I saw them they were shooting for three cents on the dollar, which is a remarkable record.

Now why? They said to their people, "You can increase the inspection pay roll if you wish. You can increase this if you wish, provided in so doing you decrease this (indicating) and end up with a decrease in that (indicating). They gave them flexibility in that department to do things which would bring about a reduction here (indicating), and then, adding the whole business together, a reduction there (indicating).

I can make this clearer, gentlemen, by saying to you that when management freezes those two items there (indicating), when management says, "Not one cent for inspection. You can't buy any more equipment"--when management freezes those two things they automatically freeze scrap and rework.

There is another little story that goes along with that, made in this same plant, which has to do with the subject in a way. It costs money to produce better quality. This one curve, we will say, starts at

about 50 percent scrap and rework. The scrap and rework will gradually be reduced toward zero. The cost of producing that reduction in that curve has a tendency to run something in this shape (indicating). In the average plant, and in the average department, the optimum point is a two percent scrap and rework loss. Supposing it was insisted that not more than one percent was to be allowed, and supposing the one percent figure occurred there (indicating). You can see from this chart the great cost involved in obtaining one percent as compared to two percent.

I am simply throwing this out as philosophy, gentlemen. The cost of getting quality must be evaluated against the value of quality if I may put it that way. Is it worth it to have, or attempt to have, a perfect product? Or can you have a little loss that way? Then, going the other way, are you having too much? Those are just two little economic thoughts that I wanted to throw at you.

While I am here at the blackboard, I want to speak about indicating gages. I have already mentioned the Buffalo situation. I have already mentioned the importance of getting into the operator's hand the gage he can use. Now a psychologist tried this experiment. He blindfolded a man and, keeping him blindfolded, told him to draw a four-inch line. Then he removed the blindfold and asked him to draw another four-inch line. He kept up that procedure for about six times. Then he removed the man's blindfold and let him look at what he had drawn. He also let him look at a ruler. Then he put the blindfold back on him and had him draw a four-inch line within a certain tolerance. After taking the blindfold off and putting it on several times the man drew a line that was four and an eighth inches long.

You see, we put blinders on our average operators. We don't give them something where they can see where they are going. I think that little test is perhaps one of the principal arguments for getting away from the Eli Whitney type of gage and getting over more into the indicating type of gage.

I remember one plant where we had one of the indicating types of gages. (Any one of them here will do as an experiment.) The operator had it for a few days. It had not been bought. It was necessary for us to take it away from him. When we picked up the gage and started off the operator said, "Say, Bud, where are you going with that gage?" Well, we tried to explain the situation. We told him it had not been bought; that it was just on trial. He shook his head and said, "You've got to give me either that gage or its equivalent, or something else." He made a great issue of it. Needless to say, the gage stayed.

Then we asked him why he wanted to keep it. We said, "You've always had something else here for all these years." He said, "Were you ever driving at night and had your lights go out all of a sudden? What did you do? You stopped--sure. Well, I've been blind all these years. Now I can see what I'm doing."

Then there is another thing that happens many times in a shop, especially on screw machines. You will see an operator equipped with six, eight, or ten different gages. He will have two or three sizes--snap gages, air gages, a pair of "mikes," maybe a plug or two, maybe a vernier caliper. They will be on his bench. Off comes the piece from the screw machine. He reaches for this. He reaches for that. He finally reaches for something else. Maybe he gets tired and just takes a chance. So we are trying to urge on industry, and we are trying to have available, gages arranged so that you can take the piece and complete the measurement of it in one motion rather than to be bothered with all the other gages.

(Mr. Kennedy picked up one of his exhibits.) I will have to hold this a little on end. But this is a four-dimensional piece, including diameters, concentricities, and lengths. The fellow gets a job done in one motion. He will measure under these circumstances and he will know what he is doing and you won't have to have that inspection crib down there.

Now let me talk for a second or two about quality. Basically, that is what we are interested in. You know a design is right. You know if it is made that way the thing is going to function. Someone was telling me just the other day he thought a mistake had been made on some of this atmospheric work where a little error of a few millionths of an inch was being allowed. They figured it out that by the time it got halfway around the world it would be two or three minutes out of its course. They wondered if they could get closer than that. The design of the thing was right. The question was whether we could hold it to those millionths. That goes all the way through any production.

Suppose some time in the future you strike some industrial plant, as probably some of you will, where it is putting out some product in which you are interested. You know from reports you have received that the product is no good. Perhaps part of your problem is to decide whether you are going to keep that plant on the roster, or whether you are going to kick it out and take on another. But you want to give that plant another trial. You want to give it another chance.

So far as conformance is concerned in gaging, quality, and things of that nature, the prime thing, I think, is to do something about it. It isn't sufficient to sit at the desk and dictate a letter in which you say we must have this or we must have that. It isn't sufficient to sit there and pound the desk and just talk about it. Do something about it! All I am urging you to do, if you have a quality problem, is to get your coat off and see that the thing is clinched.

Now you have the job running with this toolroom gage of which I spoke. You are having some trouble. You pound on your desk. You issue all kinds of directives. That won't help. I can tell you right now this blooming gage is burred on the edge. It wouldn't measure within five one-thousandths correctly. (I picked it up from a machine in that condition.) All right. Supposing you went to that job. For only $10 more you could supply this gage made by Taft-Peirce. You notice these little things here (indicating). Well, if the fit is tight, it's a heck of a job to get a plug gage down there. They usually use it as a reamer, anyway. Taft-Peirce got out this ball thing and the blooming thing drops right in. The operator can use it easily.

But there (indicating) is something new--Norbide. How many times will you gage with this before it is worn? Give me a quick answer--even a quick guess.

(From the audience): Once.

MR. KENNEDY: Good. That's exceptionally good. It is one time. You never know whether this thing is right or wrong. This (indicating) thing here will gage a hundred thousand times without any wear. That is the Norbide. It's worth a few dollars extra. But, if you drop this thing, it will shatter. Then you have to buy a new one. In Denver, where I was, we had glass gages. When they first came out, I went out there and talked to the people at the machines. I said, "This is a glass gage. We're having a little trouble getting gages. Take extra precaution when you use this. Don't drop it!" By golly, when I went out next morning those fellows were gaging for a change instead of reaming a hole as they did before.

So, gentlemen, do something about it. That's what I am after.

I can give you another illustration. We make micrometers. But here is a little shop crew with so many machines. They can turn out, say, four hundred an hour. I might tell you gentlemen so far as I am concerned 99 percent of the fellows I see on the machines want to do a better job. Ninety-nine percent of them are disgusted, either consciously or unconsciously, with the fact that they are forced to do shoddy work.

Well, this fellow has a little conscience. These pieces are pouring off. He grabs one. He has to get his "mike" on this shoulder. Then he has to get it up here (indicating). If he is like me, he has to look at it with bifocals in order to read it. He rolls it on his arm and gets it all full of hairs, which doesn't help any. All the time he is standing or leaning a little bit forward. The biggest muscle in the body becomes most tired.

All right; let's do something about it. As it is, he certainly isn't going to be able to measure many pieces. Let's give him a clicker like this (indicating). Anybody can read a clock. You learn to read a clock when you are very young. (Holding up gage) Here is one dimension; there's the second one; there's the third one; there's the fourth one. Will he get it right? The clicker is probably $30 more than the micrometer, in some plants you would think you were asking them to buy the Empire State Building if you suggested that they install the clicker.

There is one more little point in this background: Don't let them put a gage on a job with, what we call, too fine a discrimination. That is an inspector's trick. Your tolerance is plus or minus five one-thousandths. An inspector will stick a gage on that will measure a tenth every time, when all you need is a gage with a tolerance of a thousandth. If you have a tolerance of two-tenths, then you want the equipment that will measure down there. If you put the gage for a tenth on a plus-or-minus-five job, that brings it down to a discrimination that is not necessary. So let's have the gage within the field where it belongs and not follow the natural human tendency of getting it too fine.

So, gentlemen, starting with just plain, elementary measurement, let's proceed step by step and work up through these gadgets here (pointing to the items assembled). I hope some of these things will work.

First of all, I must apologize. I think probably within this three-week period we have a show for you fellows in Texas. We have another one out at St. Louis University. Then this one here this morning. I am due in Pittsburgh, at Westinghouse, tomorrow. There is another one in Connecticut; also a fifth one. I don't think we have a gage left in Providence. I wasn't able to ship here some of the things I had hoped I could. But we will do our best with what we have.

We will start with this very elementary form of measurement, namely, the steel rule. Here, gentlemen, is a simple steel rule. You lay it on the piece on which you are working. Before proceeding, I want, for your notes, to make this reference: Don't let anybody measure closer than a sixty-fourth of an inch (fifteen one-thousandths) with a steel rule. They will tell you they can, and some old-time mechanics can get down to two or three one-thousandths. But you never know the day when they are going to slip over the line.

Let's establish this thing at about fifteen one-thousandths. For rough castings and things of that nature, there is no need of buying anything more expensive, or anything better or different.

The next thing is the fact that a Frenchman by the name of Pierre Vernier took the steel rule and arranged a little system of dividing up

the scale so that you can read directly and readily to a thousandth of an inch. Today, we have what we call vernier equipment. We can measure straight lines and we can measure angles with vernier equipment. That is good up to thousandths of an inch. Don't expect it to do any better. You will see some shops where they will try to measure a tenth or two. They will tell you it is all right. It's a question whether to believe them or the old professor here.

Of course the most common and useful thing in the measurement world is the micrometer, using the idea of forty threads to the inch. That is to say, when you make one turn you have advanced an anvil a fortieth of an inch. By subdividing the barrel into twenty-five parts--one twenty-fifth times one-fortieth is one-thousandth. So if you move that only one of those graduations you have closed this gap a thousandth of an inch.

By means of a vernier device you can reduce that to a tenth. People will say that you can measure to a tenth of a thousandth of an inch with the ordinary micrometer. The old professor says that you cannot. Don't expect micrometer readings closer than two-tenths. In the first place, if I measure a piece with this, to a tenth, we will be off a tenth or two depending on the amount of muscle you put on the screw. You should have seen some of these western ranchers when they were making some measurements. In some cases they went over a range of five one-thousandths of an inch.

Let me tell you some of the limitations on that. When you are measuring closer than two-tenths of a thousandth of an inch one manipulation of the instrument you are using will make more errors than the instrument itself will. Then you have dust, dirt, and temperature, which are immediately effective when you get under half a thousandth. So let's remember there are limitations as to what we can and can't do.

This has to sound a little like a commercial plug. There (indicating) is an indicating "mike." We happen to have the Zeiss patents in this country. The European patents are used by other manufacturers. When you put a spring loaded device on the micrometer and an indicator you can measure to half a thousandth. Your indicator expands the readings so that you can read them readily. But you must not forget temperatures. I have already changed the reading of that micrometer about a tenth simply by grabbing it.

Another thing: Most people, in using any type of gage, try to make the gage read what they want it to read. Normally, one clamps the piece, unconsciously--and in so doing changes its reading by half a thousandth--either because he is trying to make it read a certain thing or he is just naturally clamping it.

One of the most difficult lessons to learn is to let the gage do its own work. If I could get all of you to finger this little gage, and then have you measure that piece, you would find yourself off by several thousandths, simply by unconsciously clamping the piece. If you will let the gage do the job, you will get the correct measurement.

The next step in this procedure is this type of gage, known as the conventional type, snap or plug. You hear people say, and they claim over and over again, it will hold a measurement down to two-tenths of a thousandth. The old professor says it won't. You have temperature and you have wear constantly in this type. You may say right off the bat, "Yes, you have wear with this" (indicating). But on this type (indicating) of gage, the indicator shows the wear right off. You do not have anything telling you here (indicating) unless you can look at it or feel with your teeth and see what the wear is.

I have here some pieces I made up for the Westinghouse crowd tomorrow. They all fit this snap gage. None of them are too small and none of them, apparently, too big. The question we are going to propose to those students tomorrow is, "With these pieces coming from the machine, and using this gage, when will you shut down the machine?"

In this particular case, the operator didn't stop his machine and he got out-of-tolerance work. By using the indicating type of gage, as he put in one piece at a time, his indicator moved up. Inside half an hour it had gone up nearly a thousand from the size he had half an hour ago. He could see where he was going with them. He could see he was near to the line. When he got to this size (indicating), he changed his machine in time and brought it back to the low size.

Following the thought I just had, when you get the indicating equipment you can measure to a tenth of a thousandth,--that is, ordinary mechanical indicating equipment, provided you do not clamp the work--that error can always be present, and provided you do not have dust, dirt, and temperature. We try, in our designs, to overcome the effects of temperature and wear. We also try to overcome the effects of clamping.

The gage I showed you (indicating) offsets all those things I just spoke about. All you have to do is drop in the piece. If you are going to get closer than a tenth of a thousandth, get something else besides mechanical indicating equipment. Oh, you will be told you can work to closer than a tenth with indicating equipment. Again, I wouldn't believe it. I would get something else.

Indicators will vary in size from Little David here (indicating) to Goliath, there (indicating). They come all the way in between. You see some samples here. Sometimes the operator needs to look a little closer than a small indicator will permit. Sometimes you have only a

small amount of space to stick in one. On the other hand, if you have the room for this, give him a big one. It sort of blows up the dimensions. So you see, gentlemen, you can have all sorts of sizes in that.

Here (indicating), as long as I have it in my hand, is a caliper with an indicator on it. Where you must caliper something, you can get it much more accurately and quickly with an indicator. (That sounds like a commercial plug, but let me say again I don't intend it that way.)

Depth is a tough one. They have a device made, something like this (indicating)--a vernier depth gage--that you can stick down into a hollow and slide this slider and measure with it. But for depth, if you can get something like this (indicating), you can get the depth of the hole quickly and accurately. All I am trying to show you is how quickly an operator can get it.

I won't be able to show this one. There (indicating) is a bore. Here (indicating) is a gage for measuring a bore. It is an inside caliper. When the caliper is actuated, the indicator gives the reading. It has a little device on it so that it will centralize in the hole. The work is in the chuck, the gage goes in, and the operator gets his reading.

I tried to set this up. We want to get a depth here (makes an adjustment on the gage); something of that nature. You can raise the work to the gage. The operator has the measurements within a thousandth, or a tenth, or whatever is necessary, without clamping it. The gage does the work.

Then you have conditions like out-of-round, eccentricity, and things of that nature. Perhaps this will demonstrate it. There is a zero reading (indicating). This piece here (indicating) is a little better than two one-thousandths out-of-round. Things like this are used on straightening operations.

Let me point out at this time that indicating equipment has this one merit that no other type equipment has: It shows out-of-round, taper, eccentricity, and those sorts of things. The conventional type equipment simply gives you the greatest dimensions and that's the end of it.

Out-of-round is important for several reasons. If you have a perfectly round hole and you have an egg-shaped shaft, to fit that hole the assembler will put them together. If that is down in the innermost parts of your automobile, what is going to happen within a few miles? It is almost, literally, a running windmill on the inside of that barrel.

Then, too, if you have what we call a back-taper, and that goes into a hole, it breaches it and immediately your hole is too big.

There are all sorts of things that you want to know in addition to these basic, dimensional allowances and tolerances. These are things that modern gaging techniques are catching. What I am trying to point out, gentlemen, is that a few years ago, with conventional gages, micrometers, and things of that nature, you could show, you could prove, you could feel that a shop was doing very precise work, but after the apparatus was assembled and out of the shop it ran for a little while and then it was shot. That was our trouble, because similar conditions were not discovered.

These things are as important, even more important, to the wear of the product than the actual dimensions. You can have a shaft and a bearing. If both of them are perfectly round and have what we call a clearance of a thousandth of an inch, and you get a better running, much longer lasting apparatus from it, like an automobile, then you have a shaft, a bearing, and a clearance of only a tenth of this condition. Your basic dimension does not always help you in the final wear of a product. So, in a sense, that is why I had this little demonstration here. This item, on the bench, will show the same effects.

I was asked to be sure to point out, so far as I could with the apparatus here, some of the advances. Up until now I have talked about things that I feel very sure almost everybody in the room knows about, has used, has run across. They have been with you for years.

I made the statement earlier that I thought measurement was now a little ahead of industry. We have gone into the use of air for gaging. You have already heard of air gaging. We can use air gaging for either inside, or bore, dimensions or outside dimensions. One of the tricks about air gaging, which is very favorable, is that there is no clamping, or things of that nature, by the operator.

Then, too, dirt and grease do not affect the measurement. Air gaging gets around that. I hesitated there for a second because you can have a degree of clamping, a degree of dirt, that even air gaging won't get around. But, in general, with air gaging all the operator needs to do is to apply the gage and the air does the work.

I am not going into the principles of air gaging any more than to say that the caliper in an air gage is always a pair of jets, out of which air is flowing. The pressure of that air is measured with either a dial or manometer. When you change the direction of air, you change the back pressure and the change in back pressure is registered. So that when you have the air flowing freely you get a certain pressure. Then, when you put in the workpiece you change the back pressure. The closer the workpiece is to the air jets, the more the change is. From that we have been able to work down to a half of a tenth in accuracy. Air, surprisingly, is that accurate.

Another thing we overcome very largely with the air gage is the temperature effect. The apparatus I have here this morning is a duplication of a job being done for the Chrysler Company out in Indiana—making wrist pins. You get absolute diameter, you catch ovality, taper, eccentricity, and tension with this apparatus.

The first trick to master, of course, is to set the basic size. That is what this thing is here (indicating). By sliding that scale a little, that water goes down to there (indicating). Perhaps some of you could not see it. It is at what we call "zero." That is the basic size that we want. All the operator has to do is to put the piece in there (indicating); that piece is a couple of tenths oversize, and if his eye is quick--it usually is--as he slides the piece through he will catch the taper. He will see it move on the little dial. Then, if he twists the piece, as he usually does, he will catch the ovality.

This particular apparatus was set up right by the "centerless" grinder. As the pieces came off the grinder they were fed through the gage. As fast as they came off the grinder, they were immediately discarded or used right there. That's all there was to it. It got out-of-round, taper, and all the elements they wanted in one bunch.

There, briefly, is air gaging. You can forget, within reason, dirt and grease. All you need to do is to throw the piece at it. Any fool can use it after it is once mastered.

The next things I want to point out are the electrical gages. Also, I want to mention a trend in gaging which is coming along. That trend is to make gaging apparatus which will fit on or over the work, in some way, right while it is being ground or turned. In other words, it gages the piece that is being formed. This (indicating) is part of a grind they have which is suspended on the grinding machine. It is put on the piece, beside the wheel, close to the wheel, and the coolant flows over it.

Now we can add to it this (indicating) electrical arrangement. (You can read it all on the indicator, but we add this electrical arrangement.) If he grinds and gets to the "green," he is already near to size. When he gets to the "red," he is at size. All he has to do is just watch the lights and there he is. He doesn't even have to bother looking at a needle.

You have transmitted an impulse here. You can build up that impulse through relays. The relays, in turn, will slow the machine down to half speed, right here (indicating), and right here (indicating) it retracts the wheel and stops the machine. We have an apparatus like this at one of the Chevrolet plants, for instance. That plant is doing a

completely motorized job on crankshafts, where one girl stands and pushes a button and an automatic conveyer brings a crankshaft over here, puts it into the machine. (She does have to turn two levers, I think, on some of these.) Now she pushes the button; in goes the wheel; the machine stops. The wheel is retracted. The automatic conveyer comes in, picks up the crankshaft, and carries it on to the next operation.

Well, I have taken you gentlemen down to a half a tenth of a thousandth of a dimension. That is the best air gaging can do. When you get below the tenth figure, you want to start thinking of something besides mechanical indicators, "mikes," and things of that nature. Incidentally, the air gage is the only known solution, up to date, for bores. So far this morning we have been talking about the O. D. The next thing is an I. D., a bore. With the air gage you have no manipulations, no worries. It is the "cure" for boring (if I can put it that way) conformance. Don't let them kid you that they are too expensive. Remember what I said earlier. That $10 gage over there (indicating) is much more expensive than this $350 piece of apparatus here, if you are concerned with getting around 99 percent of your product right. Incidentally, this, in the hands of an operator, will eliminate that tremendous inspection pay roll you have, and a lot of other things.

Next we come down to millionths. We have two basic things. One of them I can't show you here, that is, the use of light waves (the spectroscope). There is an instrument where you actually count light waves. You can measure millionths very readily if you have the apparatus. I think there are ten or fifteen of them in the United States.

From those have come the thing known as "Jo" blocks. They will get you an accuracy of about two one-millionths of an inch. This one (indicating) says one inch. This one (indicating) says half an inch. You are able to link the two of them together and have an inch and a half to an accuracy of a couple of millionths. You can build these up to any lengths.

There is one basic thing in measurement: Don't let any shop that you have anything to do with, if you are working closer than a thousandth of an inch, go along without the proper equipment in gage blocks. Incidentally, these things wear almost immediately. You don't know just when they are off. So the trick is always to have two sets: One that you use for reference, to know whether and when this set is worn; when this set is worn, get in another one. But they are definitely the things to have.

Well, coming close to that and coming close to millionths of an inch is the electronic system, which is illustrated in this instrument here (indicating). It combines one or two features of the ordinary radio set.

The mechanics of the electronic system is a spindle, right here (indicating), which moves up and down just the same as any gaging caliper. As that spindle moves up and down, it changes a system of condensers inside here (indicating), and that impulse, or change, is taken over to a box which is full of radio tubes. The radio tubes transmit the measurement, then, to the dial, to the lights, or anything else you want. This apparatus and most pieces of apparatus like it are built so that you can measure to an over-all tolerance of three one-thousandths; or, by clicking a little switch here (indicating), to one-thousandth, or to an over-all tolerance of three-tenths, or to an over-all tolerance of one-tenth. When you have an over-all tolerance of one-tenth, you can read your millionths of an inch on the scale.

When I have it properly set, all I need to do is hold my hand to within half an inch of that instrument, or even stand close to it, and you will see this begin to move. That is the effect of temperature. When you are working in millionths of an inch, gentlemen, you have a very touchy situation. Let us not be glib about it.

This apparatus (indicating) has some advantages which are apparent to the average man, after you show them. In the first place, all you need to do, assuming this is the master piece, is set the instrument mechanically so that the indicator shows on the dial, and then we set our zero electrically. (Mr. Kennedy made an adjustment on the apparatus.) All I did was turn that and get the hand to zero. That is my master dimension. From then on things will be plus or minus zero. I can set the tolerances by moving the little tolerance levers here (indicating). I can simulate measurements, as if I were putting other sized pieces in there, by changing this dimension. (Mr. Kennedy made an adjustment.) You notice the light changed just then. I have reached one of these tolerances. It is about minus a thousand. Now I will turn that the other way (Mr. Kennedy adjusted the piece). Somewhere, right in there, I moved it too fast. Right there (indicating) I hit the other tolerance of about plus a thousand.

Now that my instrument is set, I can go back to my zero, here (indicating), as shown on the scale. I will pass piece after piece through there, and if they exceed a thousand, either side, one or the other light will go on. You can have it blow a horn or ring a bell. We have blind people operating these instruments. By wearing earphones, the tone in the phone tells them where they are, and things of that nature. With this apparatus here (indicating) you can build it up to do anything you want.

The machine that I wanted to have here today is about so big (indicating). It is for ball-bearing races. The races come off the conveyer line, drop into a hopper, go through an apparatus like this (indicating), and come back out of the machine all sorted in grades of

ten one-millionths, approximately, ready for assembly. It is just as automatic as that, provided you have a guy who knows how to set it.

There were supposed to be, in the box outside of the auditorium where you got those books you have, some pictures describing these things. I don't know whether that particular package was discovered, or not. You can get them on your way out. Here are a few photographs: This is one from the Esterbrook Pen Company; one from some of the automobile companies; another one, an experiment on automatic gages, illustrating some of the developments from this point here.

I think I have covered nearly everything that I should within the time limit allowed here. I was reading the other day that if an orator talked at the top of his voice for an hour, and if his audience collected all that energy he expended and converted it into useful kilowatt-hours, it would be worth three cents. I hope you have gotten more than three cents' worth out of this.

Thank you for your attention, gentlemen. I don't know whether you want to ask any questions now or just what procedure you wish to follow.

COLONEL HENRI: Gentlemen, for the students, we will leave copies of the photographs in each one of your boxes. The guests may take away copies if they so desire.

So far as questions are concerned, Mr. Kennedy has very kindly offered to stay over this afternoon. We have arranged for an informal seminar. The gages will be left here for your benefit. We will start our discussion with an explanation of where quality control and inspection fit into a manufacturing organization. You are all invited to attend.

Mr. Kennedy, on behalf of the College, I certainly thank you for this most interesting display and for your very instructive lecture. Thank you, sir.

(23 May 1949--750)S.