GAUGES

14 March 1950

CONTENTS

Page

INTRODUCTION--Lieutenant Colonel Frederick A. Henry, USAF, Member of the Faculty, ICAF..... 1

SPEAKER--Mr. C. W. Kennedy, Quality Control Engineer, Federal Products Corporation..... 1

GENERAL DISCUSSION..... 19

Publication No. L50-109

INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

RESTRICTED

Mr. Clifford W. Kennedy graduated from Worcester Polytechnic Institute in 1917. He then joined the Remington Arms Company (U.M.C. Bridgeport Connecticut Works) as a factory engineer. For over two years he worked on factory layout equipment and methods connected with producing small arms ammunition. He then served the M. S. Wright Company of Worcester, Massachusetts, successively as Product Design Engineer, Service Manager, and as Assistant Sales Manager. He joined the Remington Arms Company before the start of World War II. A few months later he was assigned as Chief Inspector for the prime contractor at the Army operated Denver Ordnance Plant where he headed the contractor's inspection department. The work included devising, planning and carrying out essential inspection, quality control and gauging programs. At the close of World War II he joined the Federal Products Corporation, makers of gauges and precision measuring equipment, as Chief Inspector and later as Field Engineer. He is a member of the American Society for Quality Control, and the author of a book, "Quality Control Methods." At present he is Quality Control Engineer with the Federal Products Corporation consulting with manufacturers on problems connected with inspection, gauging, and statistical quality control.

RESTRICTED

GAUGES

14 March 1950

COLONEL HENRY: Gentlemen, the inspection by industry and the military services of the tremendous number of items produced to meet the requirements is one of the most important of the factors of production. Millions of man-hours in design, contracting, and production have been expended to produce an end item. If it does not meet the specifications, we are seriously hampered, because not only is the end item worthless, but we have wasted manpower and vital raw materials. The use of gauges and precision measuring instruments is one means of assuring that an end item will meet the specifications.

Our speaker today is an old friend of the College. He has traveled all over the country giving out this same information. I can assure you that you will be very much pleased with his talk and with his demonstrations. He is at present quality control engineer of the Federal Products Corporation and is outstanding in his field. He is known simply as Cliff Kennedy and as such I give him to you.

MR. KENNEDY: Gentlemen, my talk will be on gauges. This subject could involve a great many hours, but I am limited to a short period. So I will have to confine my talk to only a few of the high spots.

First of all, I would like to wipe out of your minds any thought that this will be a commercial talk. I am trying to represent the entire gauging industry. Naturally I am using our own equipment more or less to demonstrate what I am saying, but I do have some of our competitors' equipment here. If I inadvertently slip back into our company's vernacular, I hope you will excuse me and remember that we are talking about the gauging industry as a whole.

Before we bear down on the main target of this discussion, there are a couple of little things in the background that I would like to offer. It is like an artist when he is painting a picture. He has the main target of his picture, but he puts sufficient background in to fill it out.

The idea of measurement started probably when some man in prehistoric times said: "I want another thing like that." Needless to say, he didn't get it, because in nature, as well as in industry and everything else, duplication is impossible. If we could just simply duplicate things, gentlemen, we could do without a lot of these engineers, and that would be a decided effort.

Measurement is probably the most common human activity. You look at your watches frequently, measuring time. That is one of the common forms of measurement. Somebody mentions Baltimore and the first question that pops into your head is: "How far is it?" You instinctively measure the height of a step as you step up, or else you fall flat on your face. (There are situations at two o'clock in the morning when that instinct doesn't work so well.) When a baby is born, the first question isn't "Is it living?" or "How is the mother?" or "What is its name?" No. The first question is, "How much does it weigh?" We measure, measure, and measure.

I am not certain whether the hen or the egg came first, but so far as industrial progress is concerned, measurement and industry seem to be inextricably tied together. Whatever progress we have made in industry has been helped by measurement.

Just at present I think measurement is a little bit ahead of industrial progress. We are able confidently to determine a size difference of a millionth of an inch. I doubt the ability of industry yet to make a size difference in a machine process regularly to a millionth.

Maybe some of you don't know what a millionth is, so I will give you a little home work. All you have to do is to secure a hair and split it into three thousand parts. Then any one of those little filaments would be very close to a millionth of an inch.

Going back into history, one of the original units of measurement, used in the days of King Henry, was the distance from the end of a man's nose to the tip of his extended fingers. That became the yard. Then there was the time a little later when they took sixteen men, stood them toe to heel, and the total length made the rod. One-sixteenth of that became the foot. The Saxons used a Roman term "uncia," meaning "thumbnail," as a unit of length; and that became the inch. Even today the barleycorn, a little length about three-eights of an inch, is used in the shoe industry.

Probably the most successful thing in the field of measurement was the effort of the French, who took the circumference of the earth and divided it into some thirty million parts. They called that the meter. Then they were wise enough to divide the meter into a hundred parts, and they 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.

In France, in England, and in this country there is a length of metal called the standard meter and another called the standard yard. When you are in trouble with measurements, you can go to the Bureau of Standards and determine them accurately.

Turning to history in our country, I suppose that our gauging started with our friend Eli Whitney, the man who put mass production into the manufacture of muskets. He decided it was better to have one man make twenty parts of a musket, another man make another twenty parts, and so on. Finally he had another man put them together, assemble them. The soldiers of that time, in the Revolutionary War, liked his musket, because when they broke a part in the one they were carrying, all they had to do was to take a musket off somebody who had fallen and there was the part they needed. They could put it in their musket and it worked. Interchangeability started then. Mass production started then. Industry has adopted Whitney's idea. In fact industry has brought Whitney's idea up to the point now where the human being is little more than an automaton.

Now, Eli Whitney realized that, in order to get parts that would be interchangeable and fit together, he had to have some way of measuring them. So he designed gauges or templates, the forefathers of the presentday snap gauges, to assure interchangeability and to cut out filing and fitting at assembly. Industry caught on to Whitney's mass production philosophy and made a real science of it; but since his time, 1785, it has in general failed to progress very much in the matter of gauging. For years nothing was done to improve his methods. Industry is still using too much what he invented then.

I visited Watervliet Arsenal a couple of years ago and there, hanging on the wall, were some things that looked like tennis rackets or ping pong bats, pieces of wood with holes in them. They had found them up in some attic. Back in 1843 they were used to measure the diameter of cannon balls. They used quite a lot of them at Watervliet.

If you go to Frankford Arsenal, which is modernized in very many respects, you will see still in use there some little slabs of steel with holes bored in them. They are these same tennis rackets. In almost a hundred years there has been no material change in the type of gauge used at Frankford Arsenal. I am saying that to emphasize the lack of progress, the fact that there is something better but industry hasn't yet found it.

The situation is much better than it was a year ago, when I spoke here last. We are going faster. But I would like to have you help urge still faster progress, and not for the sake of us in the gauge business, but for the sake of the poor fellows on the machines, the ones who have to make the stuff. They are half blind.

Sometimes I go into shops and I see everything up to date—these ultrastyled reception rooms, parquet floors, air-conditioned shops, conveyers for handling materials, automatic machines, and IBM machines. Every modern conception you can think of you will find from the place

where they receive the materials to where they ship them out. Everything is up to date from the time we ring the front door bell until we leave. Some of them have electronic calculators that can tell you whether you slept the night before or not. You go into one of these beautiful modern plants and you get into the shop and look at the machines; and, lo and behold, the ghost of Eli Whitney pops up. For gauges they are still using the 1785 models or at best the 1858 vintage. Gauge manufacturers have not only kept up to date, as I will soon demonstrate, but ahead of the race; it's industry, generally, that refuses to obsolete the horse and buggy. It makes me feel like getting into a 1950 Cadillac but first putting on cap, goggles, duster, long cloak, gauntlets, and gloves. It's just the same sort of anachronism.

One of the reasons why we must have greater precision in measuring is because the public is demanding it. Some years ago I owned a Reo car that would do fifty miles an hour and which lasted for 50,000 miles. If you buy a car today you expect it to be able to do 100 miles an hour and to last certainly for 100,000 miles. The difference is precision, manufacturing tolerance. Back in those Reo days two thousandths was a marvelous tolerance. When they got down to that, they thought they were doing a job. Today two-tenths of a thousandth is big. "You can shy a cat through it," they say. We are getting more nearly precision all the time. I think the last thing I saw in that was in a plant in Indiana where they were grinding Diesel crankshafts and holding them to a tolerance, more or less successfully, of fifteen millionths regularly. The difference, perhaps, between the present-day and the older cars is that today we leave the extra metal in there for you to wear out instead of cutting it out and letting it lie on the floor of the shop.

You people, as symbolizing the armed forces, are partly to blame for this demand for precision. During the last war you let loose a lot of stuff about the Norden bombsight. The magazine fellows got hold of it and they glamorized it. We understood that you could pin-point your bombing and from 30,000 feet in the air hit an oil drum. The reason you could do that was that these bomb sights were made in mass production to a tolerance of tenths of thousandth.

Now what happens? A customer like me goes to a department store and buys an ordinary automatic pencil. What do I look at? I used to just take the thing and pay my money and see if it would write. If it would write, I was satisfied. Now I unscrew the cap and look to see how precisely they have made this little shoulder. Even women have been getting that habit. If we have had no other pressure, we have introduced public pressure for precision, for greater wear and greater interchangeability, in addition to ordinary production demands.

In your contact with industry and in considering the part that gauging will play in production, I would like to offer just this suggestion: You will meet up at times with industrial plants and with industrial planners. I don't care what they are making. Let us say it is a part of a fuze. A lot of money has been spent on the design, that has been finished, the tolerances have been set, and the experimental work done. We can even assume that a sample part, a prototype, is available, on which production has been tried. At least we have the blueprint of the object.

You will find then the print of the part going through a series of tool, equipment, method, and layout engineers. These fellows carefully decide what sort of machines and tools will be used and the process or routine of operations. They may decide that one part is going to be made on a Warner and Swazey machine and something else is going to be made on another type of machine. They propose factory layouts, including conveyors and handling and even the lighting arrangement. Production control schedules are organized. The stop watch boys get in there long before the manufacturing begins. They do some watch clicking and then go back to their offices and set up the incentive pay rates. You may have a pilot order or something of that nature. So the machines are there, the layout is there, and everything is going perfectly smoothly.

Then the time comes when the first few pieces of actual production come off the machine. Of course, when the first pieces come out, there is always some high official of the plant standing there. He is usually the big boss. The first question always is, "Does it meet the blueprint? Let us measure it." I have lived through all this basic experience too many times.

My first experience along that line was at the Denver ordnance plant, where I was the chief inspector. The first few cartridge points had just come out, and my big boss, who was a colonel, was standing there. He asked just that question. In the average shop, measuring equipment is about as common as fire extinguishers or sprinklers or the air you breathe. Somebody has a pair of "mikes" or something to measure with. But not at that prairie plant at Denver. Instead of the boys carrying "mikes" in their pockets, as they usually do, it was more natural at this plant for the boys to carry guns in their holsters. My face was a beautiful pink. I had to send a man nearly half a mile, away over to the tool shop, to get an ordinary pair of "mikes."

Those ranchers out there just naturally didn't have micrometers or any other measuring tools in their kits. On the other hand, no matter how up to date the factory, many modern products are sufficiently intricate in design and the specifications call for such precisions in manufacture that traditional and stereotyped gauging equipment simply will not suffice. A special type of gauge is needed.

What I want to point out to you, who are part of this picture, is that as a product is being designed, as the process and machining are being worked out, right then is the time to select, design, and decide on gauging equipment. Inspectors and gauge makers can read blueprints. All they need is a print of the part to be measured. Or, if we can get one sample, that is very helpful. We can figure out all that is necessary in the nature of gauging equipment and inspection procedure. We can set up the quality control routine way ahead of time and have that all in. We may have to cocoon it for six months or a year while we are waiting for the other equipment, but we know the thing is ready to go. I would like to throw that suggestion at you if I don't do anything else in my somewhat limited time here.

The next point that I would like to bring up briefly is that in anything that you have to do with gauging equipment, you are likely to buck up against inspectors, engineers, and men of that type, laboratory men--certainly a bunch of men who will not have to make the article. They won't have to stand at the machine all day long. Some of them never have. They don't have even the remotest idea of what that is like. You should plan, design, and purchase your gauging equipment for the operator, not for the inspector or the engineer or anyone else. The fellow to be thought of is the operator on the machine. If you make a situation so very difficult for that man to measure what he is doing, he won't measure it. If it tires him to do so and he is on piece rate, he is going to take care of his pocketbook and say "To heck with the size." So my next little warning is to design anything in connection with gauging pretty much for the man at the machine, at the operation, who is making the stuff. If necessary to have some inspectors, all right; but let them use the operator's gauge. If the laboratory man has to learn something about the part, O. K., bring him in, but let him use the same gauge.

Here is an economic gem, gentlemen: The closer to the source of manufacture you can get the decision made that a part is right or wrong, the less that part will cost you and the better will be the product you ultimately assemble. That is all there is to it.

It is better to prevent than it is to correct or sort out. The best solution is to make pieces right in the first place, and the only man who can do that is the operator. But he needs the equipment to see what he has done.

I wouldn't want to miss this opportunity of telling you about a Buffalo plant where they were making some steering gear parts on grinders, and those fellows were trying to hold them to a two-tenths tolerance. All they had were some little old "mikes." They would take batches of parts from the operators and carry them about fifty yards down the line to where they had a little air-conditioned room all prettied up. In there

was a bunch of girls and fellows, inspectors, and they inspected every part. But these inspectors had one of these $500 electric gauges that will measure right down to a millionth. I don't know whether any of you have ever seen an inspector measure with one of those things where he knows he can detect a millionth. He will find a zephyr if it is there. About three days later this man on the machine would get a report from the inspection room--let us say this is Tuesday--that: "Last Friday you made 8 percent scrap."

If you ever have anything to do with a factory, please remember that Buffalo plant and don't have your inspection down the line with the report coming out a day late. And don't have inspectors with better equipment than the poor fellow on the machine. That is another piece of this background that I wanted to get across to you.

I will give you another little instance of industrial economics, and this comes in what they call management. If we could get rid of these controllers in plants, I think we would be a lot better off. Let us say that you have a boring, reaming, or internal grinding job going on, and the operator is checking with a plug gauge made in the toolroom. You go to the controller and say: "I need a gauge that will measure that hole to a tenth." He will point out that the blueprint calls for only a half thousandth, and that he can get this gauge from the toolroom for only $5. I come along as a gauge salesman and I want him to spend $165 for a better gauge or even $300 for one like this. Did you ever see a controller when you suggest that to him? Some of them faint. "Too high priced," they say. "Five dollars" is the answer. So they keep right on with this same old gauge, making 5 percent, 8 percent, 20 percent, scrap, which they throw out at assembly. If the new gauge would enable the operator to cut his scrap 1 percent, 2 percent, or even to 5 percent, to say nothing of the loss saved at assembly, also to say nothing of the cost of a shop shipping out defective products, how long do you think it would take to pay off a $150 gauge or a $300 gauge?

If I could only find some way to prevail on these managements that by spending $300 or $165 for the new gauge, it would pay for itself in six months or even three months, that the operator will make it pay for itself in his scrap reduction, I could save these plants a lot of money. We hear about these tremendous losses in industry, about not making their profits. You are going to hear more about it in the next two or three years. But right inside every shop they have a gold mine if they would just pitch right into it. It exists in the reduction of the scrap, the reoperation, the things they do over, the unnecessary motions their people make. One of the reasons they don't know it is there is because they are blind. They don't have gauging equipment that will tell the operator and themselves where they stand.

The only part that price pays is in comparing competitive designs. The proper gauge costs nothing. If the use of a gauge fails to reduce scrap and loss, or if losses would not mount if the gauge were not used, don't buy, keep, or use that gauge. If accountants would not only charge up the cost of a gauge to a department but would also credit to it the savings its use effected, we would have a truer picture.

Here is a little piece of economics that you may be interested in (using blackboard diagram to illustrate). In one 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 one 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 or the rework operations or salvage operations. They charged up the value of any equipment bought in that department in order to secure conformance, like gauges, 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. Then added all this 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 would be a remarkable record.

Now why? They said to their people: "You can increase the inspection pay roll if you wish and increase the equipment bought to secure conformance, provided that in so doing you decrease the scrap and end up with a decrease in the total cost of the article" (still using blackboard). They gave them flexibility in the production department to do things which would bring about a reduction in the cost of the article by bringing about a reduction in the scrap.

I can make this clearer, gentlemen, by saying that when management freezes the amount that it will spend for inspection and for gauging equipment, it automatically freezes the amount of scrap and rework.

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. (Using another blackboard diagram.) 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.

Another little piece of philosophy that I would like to give you came from an operator in a plant where I was some time ago. He had been

working for a long time with gauges of these simple types, like this plug gauge. We gave him an indicating gauge to work with for a few weeks. The controller wouldn't buy the gauge, so we loaned it to this operator, got it into his hands on consignment. When we went to the shop later to retrieve our property and started to walk away with it, he spoke up and said, "Hey, Bud, where are you going with that gauge?" We tried to explain the situation; told him it had not been bought; that it was just there on trial. He made this statement: "You have got to either give me that gauge or an equivalent or I quit my job." He made a great issue of it. Needless to say, the gauge stayed there.

Then we demanded a little further explanation. We said something about the fact that he had been using this other gauge most of his life and how did he happen to get so charmed with this one? He put it this way: "Were you ever driving at night and had your lights go out all of a sudden? What did you do? You stopped; sure. Well, all these years I have been working blind. Now I know where I stand. I can see how my work is going." For the first time in his life he was enjoying the pleasure of putting out good work.

Another thing that cripples a shop on the average machine is where the operator has some simple little part to check that has three or four dimensions to be measured. He has six, eight, or ten different kinds of gauges. He will have two or three sizes of snap gauges, plug gauges, a pair of "mikes," maybe a plug or so, maybe a vernier caliper. They will be strewn over the machine and on his bench or work stand. He has to reach around and pick up one gauge and try one dimension. He has to reach over and find his "mike." If he is an astigmatic fellow like I am, he has to get this (demonstrating) in focus and fuss with it. When he picks up a piece from the machine he reaches first for one gauge, then fumbles around for another, leans way over to find the third, and maybe hunts fruitlessly for the fourth one. By that time he's tired of gauging. Besides, a lot of his incentive time is used up. The usual result is his discontinuing gauging entirely, and he just takes a chance.

The modern solution to the time-wasting problem of scrambling for gauges is to make up a unit, multiple-purpose gauge like this one, (demonstrating). Here is a piece with several diameters, lengths, and concentricities to be checked. As you can see, the operator flips the workpiece into the gauge and, presto, the indicators tell him whether it conforms in every particular or not.

Or let's take another example. Here is a multiple-dimensional type of piece that a screw machine operator needs to check frequently. The operator measures one diameter with his micrometer, then the next one, and so on. He's using up valuable time as well as energy. Now suppose you furnish him with an indicating gauge like this one. One short

click and he knows the first dimension, another click and he reads the second, and so on. It took one-tenth the time and practically no energy. A person learns to tell time from a clock almost before he learns to read, so an indicator with a clocklike face on it is a natural.

Let me bring up another point. We make micrometers and sell a great many of them, so I am not knocking them necessarily. But here is a little four-shoulder piece. Let us do this in the traditional way. This four-shoulder piece comes off the screw machine at the rate of about 400 an hour. The lad wants to know how he is doing. You know, 98 percent of our workers really want to do a good job. So he takes this piece and he has to measure it on one side. Then he has to adjust this part up here to get the other dimension. The chances are that then he rolls the gauge on his hairy arm and gets it all full of hairs and out of kilter. He has to get two more diameters.

Let us say he has a little conscience. This material is pouring off this machine. He has three other machines that he has to run in order to make his incentive. All this time he is standing or leaning a little bit forward. Now, the biggest muscle in the body is the one that runs from behind the knee on up to the back. Being the biggest muscle, it gets the most tired. That is the one that is supporting him all this time. I think you can understand what his mental attitude will be. All we suggest, and this is not a "commercial," is that you spend just $15 more--that is all--and give him a clicker gauge like this, one with a clock on it. Anybody can read a clock.

Some of you are going to get a little workout in quality control and things of that nature in your course this week, so I would like to bring up another piece of philosophy. This will apply perhaps to some of you when you are up against contractors and these so-called industrialists. You are trying to get some stuff out that you can use, that is right. I don't know whether anybody in this room will agree with me or not, but that is about the toughest job there is. Price doesn't enter the situation or anything else; just to get it the way you want it. If you are up against a shop where out-of-tolerance work and slack quality prevail, the best way to cure that situation is to do something tangible about it. We have found that desk pounding doesn't do very much good. It doesn't bring the dimensions in. Letters don't do very much good either, or sending out memorandums or directives. We find that we have to get out in the shop and do something tangible about it.

In the first place, we have to get rid of this old nickel toolroom gauge that has been giving a lot of trouble. We have to put in the operator's hands a gauge like this Taft-Pierce model with the lead-in ball race, that measures the hole, where he can see which way he is driving. This particular Taft-Pierce gauge, too, is Norbide-lined.

It will preform 100,000 gauging operations without appreciable wear, in contrast to this old shop gauge, which is probably worn after it has gauged ten pieces.

The next step will be to furnish the operator with indicating bore gauges like this one, with which he can detect the gradual wear of the tool and resharpen or change the tool before the work goes out of tolerance.

Maybe the operator can use a vernier depth gauge. It is taking him now five minutes to measure this depth, and he is going to measure it many times. So we go out to that shop and may spend $15 more and give him an indicating depth gauge, and then he can get the depth with one motion.

I don't care what it is that you are making, if somebody, shall we say, in power in that industry higher than the operator comes out with something new, something a little different, and does something about it, your quality, your dimensions, and all that sort of thing begin to come in. So I would like to urge on you and on industrialists that, if you want better quality, get out in the shop for a while. Get your coat off and do something about it and you will get the thing that you want.

Another thing that should be brought up this morning is the question of trend. If you are driving a car down the road and you are a good driver, you keep a little inside the soft shoulder. You know that if you get over to the edge or even get on the soft shoulder, even the best driver is in a position to suddenly sideswipe a stone wall that is right alongside the road. The operators in the shops realize the logic of that principle, but they don't have good means of steering, shall we say. They drive usually too close to the edge. I am frequently amused in a shop to see the operator keeping his work near the upper tolerance because he knows that if the work is rejected, he has some metal on there that he can cut over again and bring the piece down. Nobody has yet invented a successful putting-on tool. That is a natural tendency.

Now, you kick about his work. You tell the operator that a lot of the work is going out of tolerance. Generally he will say, "I need more tolerance." Well, you double the tolerance on the blueprint. What does he do? He keeps right up in there right along the upper edge and all this space down here is gone.

So we are trying to get something that the operator can see. Here is Eli Whitney's gauge. Here are three pieces that came off the machine about twenty minutes apart that were checked with this gauge. All three pieces went in the "Go" gauge. They didn't enter the "no-go" size. He wouldn't stop his machine naturally with that sort of equipment.

Let us check these three pieces on this indicator gauge. With the No. 1 piece the indicator hand is over here at the left. Here is the No. 2 piece, which came off twenty minutes later, and the hand is up here to the top. Here is the No. 3 piece, twenty minutes later, and the hand has gotten over to the other side. It is over near that red line that is his signal to stop before the work goes out of tolerance.

But now the controller comes into the picture. We have a hundred machines to equip with gauges. This first gauge costs $15 and this indicator gauge costs $60. So we buy one hundred of the cheaper ones and we continue to make scrap and throw it out the window in our assembly.

Here is another funny thing, and all this is not a "commercial." This indicator gauge will adjust itself over a range of about six of these other gauges. He could use one indicator gauge instead of six plug gauges. Six times $15 is $90. The indicator costs $60. The controller could save himself $30 right there. Still you can't get them to do it.

There is another bad condition in industry which you will run up against if you deal with industry a lot. Whether gauging equipment is used or not, there is always the situation constantly in industry where a batch of work is legitimately rejected. It contains too much out-of-tolerance work. It has gone too far the other way, or something of that nature. The fact is, it should not be accepted and it should not go through any further process. So what do they do in the average industry? They take the batch of work and they move it around to a room that is out of sight. They call it the salvage crib, ordinarily. They have a salvage committee or deviation committee, and they come daily to this area. They look over this rejected work. The committee is usually an inspector, an engineer, and a production man. They go in and they "pray" over the work. Somebody says: "We will have to have this or it will hold up this line" or it will do this, that, or the other. So he says, "Let us pass it." Or somebody says: "It is only a half thousandth oversize. That doesn't make any difference. Let us pass it." A deviation committee usually passes everything.

Now, if you have made up your minds that the tolerances and the standards are so-and-so, why then do you have the big boys come down and say in effect to the inspector or somebody else: "You were wrong to reject that. This is all right." Why do you keep changing? This deviation committee situation, I think, is one of the most serious things in industry. If you have a tolerance on your prints, if you have specifications, if you have standards, and if they are fair and proper, don't let that industry continually deviate from them or the process will get worse and worse.

Before we proceed to discuss and describe in some detail the gauging equipment that we have here, and before we get to discussing measurements in millionths, as we will, let me emphasize one more preliminary point. There is a considerable tendency, when plants go into indicating

and electrical gauging equipment, to select apparatus with what we call too fine discrimination. For instance, if the tolerances called for are plus or minus five thousandths, a total of ten thousandths, an indicator capable of measuring or subdividing to thousandths or half thousandths is plenty adequate. Don't make the operator use a gauge that will discriminate to a millionth or a half tenth unless the work is extra precise or down to, say two millionths. When a gauge will readily show tenths or even millionths, there is no need of making the operator suffer over such precisions unless the work calls for it.

My main object here this morning, as I understand it, gentlemen, is to show you the progress that has been made in gauging. I will try to do a good job of describing that a little bit.

This (demonstrating) is the traditional "go-no go" gauge, like pushing a horse into a set of shafts to see if they fit. This is the traditional gauge that Eli Whitney invented.

Probably the first step in industrial measurement was what we call the steel rule. It is just a ruler with which you can measure. It is good for measuring to a sixty-fourth of an inch. We have some mechanics who claim they can read down to two or three thousandths with a steel ruler. They may do it once by accident, but we know they can't do it consistently. The steel rule is all right for rough stuff, for foundry work and such as that.

Possibly the next step was the vernier, this little device where you take a steel rule and put on a little graduation system whereby you can measure to a thousandth of an inch. They are somewhat awkward to handle. Usually you have to have a glass in order to read them. They are still popular. We have gotten now down to a thousandth of an inch.

Then along came the micrometers, probably the most useful measuring tool there is and in a great many respects the most accurate. Each turn of the screw is one-fortieth of an inch. Each turn is divided into twenty-five parts. One twenty-fifth times one-fortieth is a thousandth of an inch. A micrometer can be made rugged so it will stay accurate. There is probably no better invention, however, one word of warning. While they are graduated and you are supposed to be able to read to a tenth of a thousandth, we find in practice that nobody can consistently read closer than two-tenths. When you are below two-tenths, you ought to go to something else. Most mechanics by just the exertion of a little pressure or the lack of it can change a reading up to a thousandth.

We made a rather interesting experiment a while ago. Using a set of very carefully graduated plug gauges and a set of very carefully graduated holes, we had some twenty men make measurements. We jotted

down their results. We plotted what they called histograms, which some of you will perhaps get in quality control. We made a couple of calculations and were able to show, and have been able to prove since, that the possible variation, the possible error, that a man can make with this tool will go up to two thousandths of an inch in ordinary everyday gauging. Those are some of the dangers of that gauge.

The next step possibly in this line is the indicator. The indicator is accurate to one dial division. This one happens to be capable of measuring down to a thousandth of an inch. You can expect an error of about a thousandth of an inch somewhere in the use of this indicator. However, you can get indicators that will measure to a tenth of a thousandth, and you can expect an error of a tenth in the use of those instruments.

I have already spoken of the operator's ability to detect a trend that he is following if he has indicating equipment. I think that is the most important element in connection with such equipment.

We can make indicating equipment that will be useful for a number of other things. Suppose we have a recess, a pocket, a depth, that we want to measure. We can make indicating equipment with moving anvils so that the operator can get many pieces through rapidly. Or if it is something that is tubular, deep throated, we can design a gauge for depth.

One of the most interesting gauges I have run into lately was a type of caliper gauge that goes down inside a beer bottle. It folds up just like one of these ships that you put in a bottle. Then when it gets down inside, it unfolds and measures the thickness of the glass. The idea was that the beer bottlers were losing too many bottles due to uneven glass walls. The bottles exploded as they were being filled. The bottlers wanted to cut down that loss.

A similar type of gauge was picked up by the petroleum industry for measuring tubing. These things are from thirty to fifty feet long. The gauge reminds me a little of the old star gauges. We are getting now into using them with artillery.

I have spoken here of what we call multiple-purpose gauges. I brought this one along to bring up another point about indicating gauges. Let us say you are interested in an absolute dimension, be it a diameter, a bore, a length, a width, a depth, or something of that nature. But there are other elements that are essential. If you have moving parts, they must be concentric with each other. They can't be egg-shaped or oval. In fact, ovality, as the English call it, is much worse than a direct digression from tolerance. It creates more wear. If you have had any engineering training, you will realize that

there must be a certain area that they call the bearing surface. If one part that is oval is going inside a round part, you lose that bearing surface even though your basic diameter is correct, and the engine or whatever it is goes to pieces in a short while.

You have to go to indicating equipment to get ovality, concentricity, squareness, this thing we call relationship. Here is a demonstration of it. Let us say this piece here is the correct diameter, but, look, it is three or four thousandths out of round. You must have indicating equipment or something of that nature to show that the worker does have to know whether his machine is performing in true circles or doing something else.

I have one gauge here that is used by foundries. We are finally getting the foundries on the alert. A little less than a year ago the International Harvester at Fort Wayne announced that it was going to buy castings by the piece instead of by the pound. The foundry after a while admitted that it was making more money, and other foundries have admitted that they are making more money, selling castings by the piece than by the pound. The trick was, they were controlling the cores, their web thickness, controlling the amount of metal that was going into those castings. International Harvester made more money because it had less dead metal to cut off. Everybody is happy. Why? Because the foundries, instead of calipering and using a ruler, are now using indicators and getting the measurements down to a ten thousandth of an inch and getting control of their operations.

We have moved along in accuracy from the steel rule, good for about a sixty-fourth of an inch, up through the micrometer to the average indicator. In other words, we are where we can measure up to a tenth of a thousandth. Now we have to get away from the mechanical indicator, the screw thread micrometer. We have to get into something else in order to measure to a closer degree.

Perhaps the next step is what we call air gauging. We shoot air out of little jets against an interior or exterior wall of a metal body. When air impinges against something, a back pressure is set up, and you can measure that back pressure. The closer the wall of the material wraps around those jets, the less the distance, the more the air is turned or twisted and the greater the back pressure.

In measuring back pressure one way is with a manometer. Or we can use the Benturi principle, or a Bordone tube. There are several ways. This happens to be a manometer. To give you a quick demonstration of it: We have this blued up in good shape so you will see it. This plug is made for this piston, for these wrist pin holes. It contains two pairs of air jet calipers. There is one set here and

another set up here. We have two of these holes. In one motion we put on here, first of all, a piece independently measured and which is accurate. You can call it a master. By putting the piston on, we get simultaneously in one motion the two diameters. They vary a tenth or two from each other. By moving the piece around and watching those two columns, we can detect ovality and lack of concentricity. There in one motion, standing at a distance from the work, the operator has the whole picture on that piston. Incidentally, this one was defective. That is why we get these little differences here. It is oversize, for one thing. It has too much eccentricity.

Another little demonstration I might give you on air gauges is the reverse of this. Observe this air column. Here are wrist pins that go in a piston. These have to be held perfectly round to certain diameters. We have this set up so we can move the wrist pin into the gauge, then move the next one in, and keep them going one right after the other. In fact, we have apparatus like this fixed up so the pieces move right from the grinder automatically through the gauge.

That was a mechanical demonstration of what I call air gauging. The point that I wanted to bring out in particular was that with air gauging you can securely measure down to a half of a tenth. You can get your ovality and get your out of round and your lack of concentricity. It is a complete unit in itself, the air gauge, and it is solving many, many industrial problems.

I am going to move quickly into electrical equipment. First is this simple attachment here, where you take an ordinary mechanical indicator and you hook a switch on to it. Here we have a little switch box. We will assume this is on some form of caliper or gauge. If the work is undersize, the operator gets the yellow light. If the work is in size, the operator gets the green light. If the work is oversize, he gets the red light. On the ordinary run work usually starts with oversize. The operator works back to green. If he fails to regard the green he gets the undersize signal. You can use apparatus of this nature for inspecting very rapidly. You can see lights quicker than you can see the flicker of an indicator or something of that nature.

However, the next point is that, having done this, you have created an electrical impulse; and the minute you create an electrical impluse, you can build that impulse up through tubes, transformers, relays, and everything else. You can make that impulse stop the machine, make it retract a wheel, make it ring a bell, make it do anything you want it to do. The basic thing is that you create an electrical impulse due to a size difference. You can set your tolerance on that little switch, and then be getting things automatic.

If you attend the tool show at Philadelphia next year, you will see push button machinery absolutely complete, where a little girl will

push two buttons and a crankshaft will come down out of the air somewhere and fit in between centers; she will push another button and some milling cutters will go to work. One of these little gadgets will automatically set the stop switch when the thing is in size. She will push a button and a conveyer will pick up the crankshaft and carry it over to a grinder. A girl on the grinder goes through approximately the same cycle. Two girls instead of thirty men. You know, every man here is soon going to have to put on an apron and work at home. I just brought up an economic problem, by the way, of what automatic measurement is going to do.

Of course, the accuracy of apparatus of this nature is dependent on the accuracy of the indicator. With a mechanical indicator you would be confined to a tenth or a half of a tenth. So, to take that a step further and getting down to the finest thing in measurement that we have today, I brought along an instrument which measures in millionths of an inch, an electronic setup.

With a setup of this nature we gain a number of advantages. In the first place, we have lights here in the same way as we have them over there, the green and the red and the yellow; but we have a couple of other features in addition to the meter. We can regulate this sort of apparatus to tolerance electrically. By turning a dial in the same manner that you turn a radio dial you can set the gauge for the mean dimension. If you want to run it for tolerance, you can set it up to some tolerance or other. Now that is set for the lower-size piece. I can change that if I want to by again moving the dial. In other words, we set electrically our tolerance limits. I can go up to the high or plus side. I can change that condition by moving a dial. It is just as simple as that for the operator to change to a different set of specifications.

I have this thing set for millionths. This hand is now at zero. Notice that just the slightest pressure of my fingers on the back of that column has changed it some twenty or thirty millionths. You can change the reading by breathing on this instrument, or by the proximity of your body. We have instrumentation, gentlemen, which will do stuff that as yet the average machinist or operator can't meet. Or, to make it practical, we can change the scale here so that it has a limit of three tenths instead of one tenth or a thousandth. In other words, it can do rough work or it can do fine work. You can do the whole business electrically. This gauge is pretty near the last word.

Another advantage we have here is that there is absolutely nothing mechanical to wear. This is a floating sort of device. The action inside is electric. It is all in air, all suspension. There are no bearings. In other words, you have endurance forever. You can't wear it out.

We passed around some sheets, gentlemen, with some pictures on them. They illustrate what I said--that by taking a basic electrical circuit and creating an electrical impulse inside an instrument, you can build it up through relays or tubes and things of that nature and make it do anything. In the upper left-hand corner of this first sheet is shown a machine through which glass tubing rolls. The picture shows only a section of the gauge. Up there you see a little indicator mounted, and some of this electrical stuff. (Sheets were not reproduced.)

Now, that glass tube moves through the production machinery and through these measuring rolls and the machine cuts it to length. As the production machinery cuts it to length, the glass tube is rolled into that hopper which you see just below the measuring machine. Now, if the measuring machine has measured a length of glass tube that is too small in diameter, the electrical circuit will remember that; and when that length of tube hits this hopper, the hopper will automatically open and throw that tube off and break it. If the glass tube thirty feet away from that hopper rolling through is the right dimension, the electrical circuit will remember that; and when it hits this hopper, the hopper will tip and roll the tube carefully down into the batch that is going to be packed. We have what we call a memory circuit now, and you can make that thing do anything you want to do.

In my last job, which was in a wire mill, the rollers were down in the basement. The whole control business for the rest of it was up on the third floor. As this wire traversed from the basement to the reels on the third floor, the electricity did its remembering, and certain lengths of wire were snipped off, and the reels automatically rolled out of the way.

In the upper right is just a section of a machine which is a step further than this air device (indicating). This is again for wrist pins. They come off the machine on an automatic uphill conveyer. They revolve through a little fan device which picks them up one at a time and rolls them through the electrical device at the bottom. That is a quick-sorting device. We are sorting these pins for selective assembly into six different classes. The machine will mark them or stamp them so that the assembly operators can use them.

On the next page, in the upper left is a picture of a machine which is used by type setters to measure the depth of type. The success that we are having in color printing now is due to the fact that we are controlling the type depth, the engraving plates, and all that sort of stuff, even the thickness of the paper, to tenths of a thousandth. That is why we are getting these wonderful color reproductions in the "Life" magazine and the "Saturday Evening Post" and so on.

The picture up at the top shows a machine where the girl puts these slugs in and the machine sorts them out automatically.

Just below is a picture of a ball-bearing sorter which is now in quite common use in all ball-bearing factories. They simply pour the balls in. The machine locates each ball, measurers it, and brings the balls then out at the left in anywhere between two and fourteen classifications five millionths of an inch apart. That is how quickly it works. We can go closer than that, but the ball-bearing mechanics aren't able yet to get a reading of twenty-five millionths out of round; so to classify much closer wouldn't mean very much.

On the upper right is a picture of part of this wire machine I was just speaking of, just the measuring part itself. To the right is a little roller which is installed on a kind of continuous machine that rolls and operates an indicating function, also a memory circuit. That big box contains this memory circuit that I was talking about. It also contains a recorder, so that the management has a record of every inch of wire going through, just what it is. One tendency now is to tear off a sheet of that record and put it in the shipment or with your bill and send it to your buyer. There is the evidence that you produced intolerance work.

We had one funny sort of reaction at this wire mill. The fellows on the mill downstairs told us this roller thing was unsafe. They said it somehow or other interfered with their manipulations of the machine. The union went to the safety committee and they said all those apparatus had to come out, $7500 worth. We went down on the job and looked things over. We thought we knew what was going on. You see, for the first time a record was being made up on the third floor of what these fellows were doing downstairs. So it was "unsafe." I just want to warn you that if you go into high-faluting equipment, remember that psychology a little bit. The workers will blame their poor work on something else if they can. You have to get to the fundamentals of the situation.

What did we do? We put in $300 extra. We put another recorder down in sight of these fellows in the basement, with this statement: "We want you fellows to see how well you are doing." After that went in, this thing was perfectly safe.

QUESTION: You have said a lot about the philosophy of gauging, but I haven't heard you say anything about the calibration of gauges. It seems to me that with the combination gauge and hammer, if you use it just as a gauge and not as a hammer, it will retain its accuracy; whereas with the indicator gauges how is the operator going to test his gauge?

Another point: I am in the kitchen already myself and I would rather use a weight pressure gauge on a pressure cooker than an indicator gauge, because I can't calculate accurately the indicator pressure.

MR. KENNEDY: With the general type of gauges exemplified by the micrometer and the vernier you have direct reading. The calibration of

it, you might say, is in the indexing. But in general, the minute you get into indicating equipment, you get into this type of gauging all the way through. You have what we call a comparator. This is direct reading over a very short range. So there is this much necessity: The operator must every once in a while put a piece in the gauge that he knows from independent means is correct in size. It does have the advantage that when he puts the independently measured piece in his gauge, if the gauge doesn't register correctly, all he has to do is turn the dial until it says "zero" and then he is on his way.

This sort of equipment will run direct readings anywhere from about a thousandth of an inch up to, say, fifty thousandths of an inch. Beyond that you have to go into other types of equipment. You have to consider the comparator, where we actually calibrate it first with a master.

Now, if you want to go beyond that in an average plant, whether you are using this plug type of gauge or a micrometer or some form of indicator gauge, you have to go to basic equipment, which is either light waves or gauging blocks. We have to check this sort of equipment with, shall we say, stacks of these gauge blocks. That is the main thing. That has to be done at intervals sufficient to maintain the accuracy.

The other point that I would like to bring out is this: Speaking of your pressure cooker, gravity, of course, is always there, but there is also friction, stickiness, and so forth. My wife has one of these weighted cookers. Every time she cooks apple sauce, it goes up through the spout and the weighted thing is no good. But she doesn't realize that until the next time she uses the cooker and the thing nearly blows up in her face.

The point is, this conventional type of gauge never warns you when it is in error. The indicating gauge will almost invariably warn you when it is itself in error. That is one advantage of it. That would be one advantage of your fireless cooker.

COLONEL HENRY: Mr. Kennedy, on behalf of the Commandant, the College, the students, and the faculty, I thank you again for being with us.

(5 May 1950--350)S