PROCEEDINGS OF WESTERN REGIONAL STRAIN GAGE COMMITTEE

STRAIN GAGES ON RAILROAD APPLICATIONS
A MOBILE-DYNAMICS TEST FACILITY
ACOUSTIC EMISSION APPLICATIONS

Sept. 17, 18, 1979

WESTERN REGIONAL STRAIN GAGE COMMITTEE

Richard L. Egger, Chairman

PROCEEDINGS OF TECHNICAL SESSION

STRAIN GAGES ON RAILROAD APPLICATIONS
A MOBILE DYNAMICS TEST FACILITY
ACOUSTIC EMISSION APPLICATIONS

Disneyland Hotel

Anaheim, California

September, 17, 18, 1979

EDITOR:

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Society for Experimental Stress Analysis

14 Fairfield Drive

Brookfield Center, Connecticut 06805

WESTERN REGIONAL STRAIN GAGE COMMITTEE

Proceedings of the 1979 Fall Meeting

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MANUFACTURERS' SEMINAR ON NEW DEVELOPMENTS IN STRAIN GAGES

PART 1

By

JAN KIRKWOOD

AilTech

City of Industry, California

Jan Kirkwood

I was really hoping for a little longer introduction. I will be very brief. We are looking toward bringing three new products to the marketplace the third quarter of 1980. But our basic dedication for the rest of 1979 and 1980 will be in the area of developing equipment and characterization for not only our gages but for testing and testing problems. Not only our testing problems internally but problems that our customers run into. So basically we are dedicated to providing more service for our customers--more information for them and for ourselves. And that will be our goal, with product development running a close second, but nevertheless second. We are in a position now currently where we have a multitude of development programs under way in our engineering group. We have been working very hard to develop that group into a responsive organization, not that it has not always been. But it has been understaffed and it is very difficult to be as responsive as people would sometimes wish us to be. We have added a product manager to that group. Al Metcalf has taken over the supervision and direction of both the engineering as well as the production groups. And with his abilities to coordinate and to control and direct, we now have a good basis for developing personnel, product lines, and testing.

MANUFACTURERS' SEMINAR ON NEW DEVELOPMENTS IN STRAIN GAGES

PART 2

By

JOHN HALL

Magnaflux Corporation

Chicago, Illinois

John Hall

Gentlemen, I am pleased to be here. At Magnaflux we are still looking for people. It seems like everyone is leaving Chicago and going to North Carolina. I do not know what is down there. However, in the new product field, we are upgrading our high-temperature brittle coating line known as Alltemp. We are shooting for a higher temperature as well as a wide-spread spectrum of coefficients of expansion for the brittle coating. As you know, earlier this year we took on the distributorship and engineering of the CERL Planer capacitance high-temperature gage. It has been going quite well. As a matter of fact, we have done some upgrading of the line. It is in stock in Chicago and there should be some very interesting material come out on that next year in the way of engineering applications.

MANUFACTURERS' SEMINAR ON NEW DEVELOPMENTS IN STRAIN GAGES

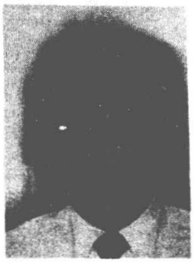
PART 3

By

JAMES DORSEY

Measurements Group

Raleigh, North Carolina



Jim Dorsey

A slide presentation "tour" of the new Measurements Group plant in North Carolina was given.

EVALUATION OF WELDABLE STRAIN GAGES FOR USE ON RAILS IN THE FAST TRACK

By

L. L. MC IRVIN
R. A. GRAFF

Transportation Test Center, Pueblo, Colo.

Larry McIrvin

BACKGROUND

Since the summer of 1975, various tests have been conducted at the Transportation Test Center (TTC) which required strain gaging the rail to measure wheel lateral and vertical forces. A test in December 1975 used Micro-Measurements (MM) weldable gages with the leads attached in the field. (Fig 1). The gages worked, but installing them in December with blowing wind and snow was very difficult and uncomfortable. In June 1976, Battelle Columbus Laboratories installed 60 Ailtech weldable, waterproof, integral lead gages on tangent track (Fig 2). These gages worked satisfactorily and were much easier to install. In August 1976, the Facility for Accelerated Service Testing (FAST) program required 136 gages to be installed on the rail to measure lateral and vertical forces. Because the Ailtech weldable gages were easy to install, they were placed on the FAST Track, mostly in 5° curves.

Before 100 million gross tons (MGT) of traffic had accumulated on the track, many of the Ailtech gages failed. The failed gages were replaced with MM weldable gages with preattached 30 AWG leads and protected with M-coat F. When the rail

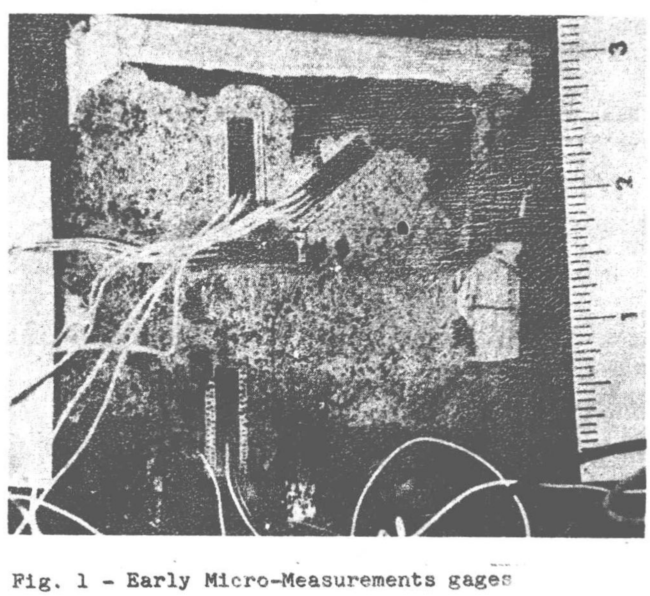


Fig. 1 - Early Micro-Measurements gages

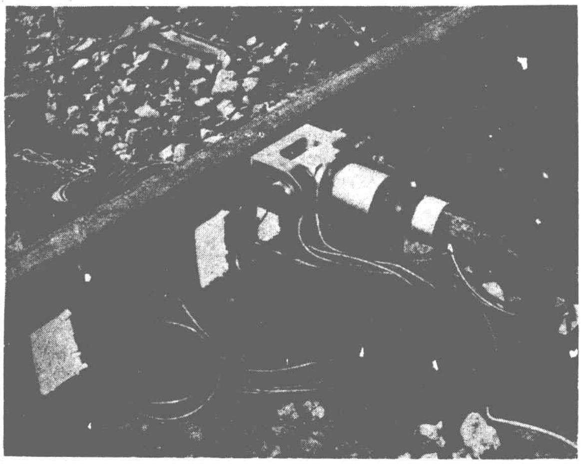


Fig. 2 - Standard Ailtech gage installation, 1976

was removed in October 1977 with 135 MGT of service, about 50% of the Ailtech gages had been replaced. None of the MM gages had failed except for some broken lead wires.

During the fall of 1978, Battelle again installed several hundred of a new version of Ailtech weldable gages on the Train Dynamics Track, 1.5° curve. No gages failed during this test, so when several hundred more gages were required for the FAST Track during the winter of 1978-79, the new Ailtech gages were selected because they were easier and faster to install. This installation was again on a 5° curve and the gages started failing almost immediately.

STRAIN GAGE ENVIRONMENT

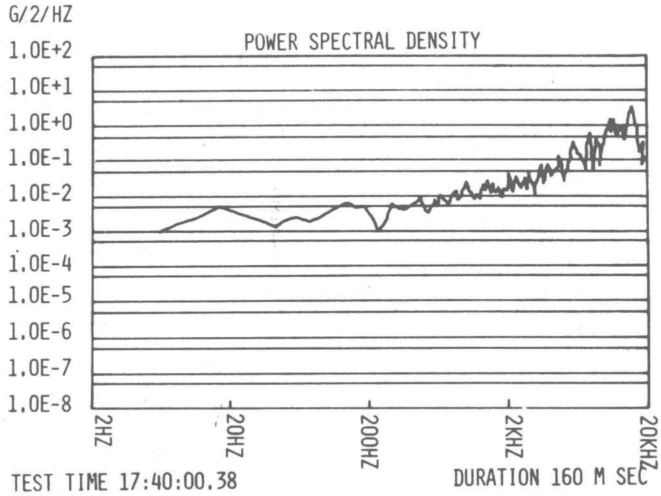
In late 1978, an experiment was conducted to determine the vibration environment on the FAST Track. Figure 3 shows the preliminary results of two power spectral density (PSD) plots from data taken on the rail vertical axis at two different times during the train pass. Figure 4 shows the same location and time samples for the lateral axis. These data were taken with accelerometers flat to about 15 kHz. A typical FAST test day subjects the strain gages to 25,000 cycles of strain at a peak level of 250 microstrain.

TEST DESCRIPTION

An evaluation test was started in February 1979 to determine the reliability of new gages on the market. The test objective was "to test the durability of five different types of strain gages in a Battelle chevron vertical circuit located in the FAST Track." These gages were installed in two different locations on the high rail in 5° curves. One location was in wood tie Section 03 and the other location was in concrete tie Section 17.

Figure 5 shows the layout and wiring of the vertical gages and Figs 6 and 7 show the lateral circuits. Lateral circuits were added to obtain preliminary information on circuit performance and to allow more gages to be evaluated. A secondary purpose of the test was to record installation times so that if more than one gage survived the environment, a selection could be made on factors such as installation time, cost, and availability.

The five gages were originally selected because they were the only gages available at the start of the test. However, a train derailment caused the



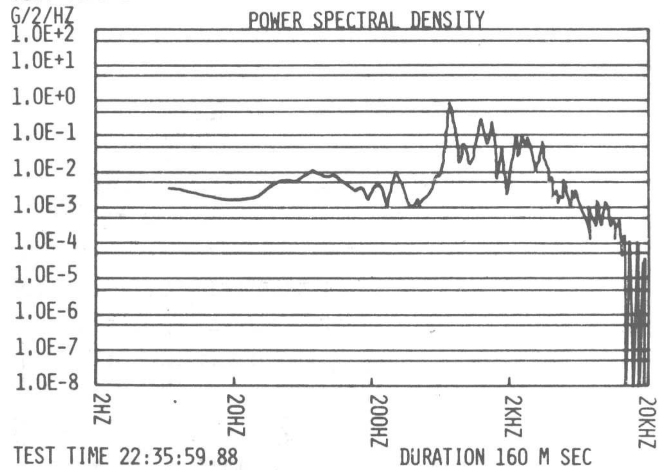


Fig. 3 - Accelerometer location tie #17-0359
Outside rail vertical axes

starting date and duration of the test to be extended, and allowed more gages to be included in the durability test. In addition, a second test was run to evaluate the performance of the two more promising gages from the durability test and a third gage, which was a modification of another gage, from the durability test.

Table 1 summarizes the types of gages evaluated in the durability test and Table 2 is a summary of the gages evaluated for performance. All photographs are referenced in these tables. The performance parameters of prime interest were linearity, crosstalk, and hysteresis.

RESULTS OF DURABILITY TEST

For the first two months of the durability test, the static balance of each circuit was measured and recorded daily. For the last two months, the static balance was measured and recorded every week. These data were used to determine when a gage had failed (indicated by a large shift in the balance point). In addition, dynamic data were recorded from all working circuits during the last month by recording the circuit output on analog FM tape as the train passed.

AILTECH RESULTS

None of the Ailtech gage installations lasted over 10 test days and 50% failed after the first

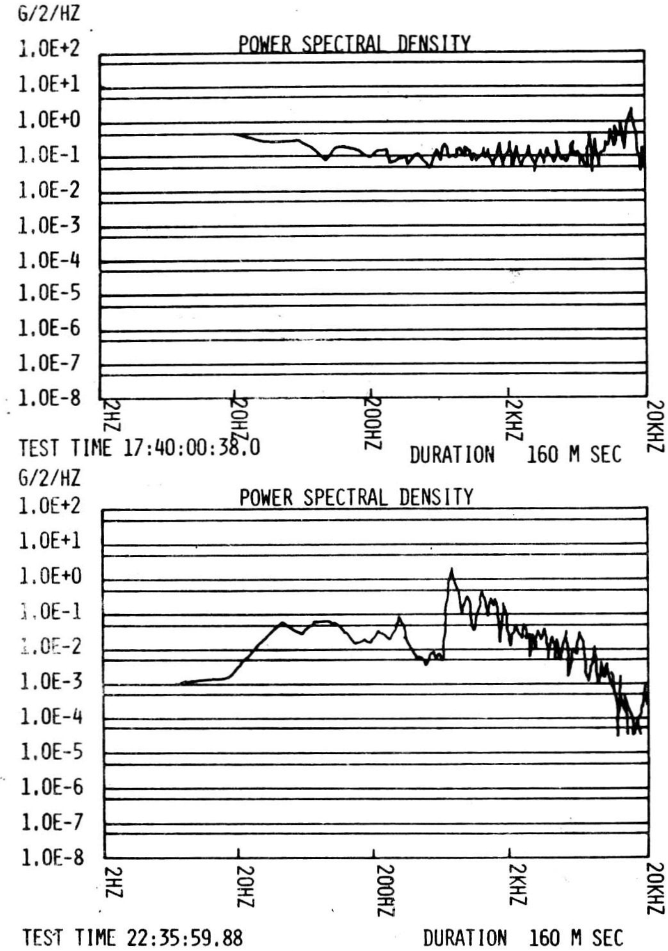


Fig. 4 - Accelerometer location tie #17-0359
Outside rail lateral axes

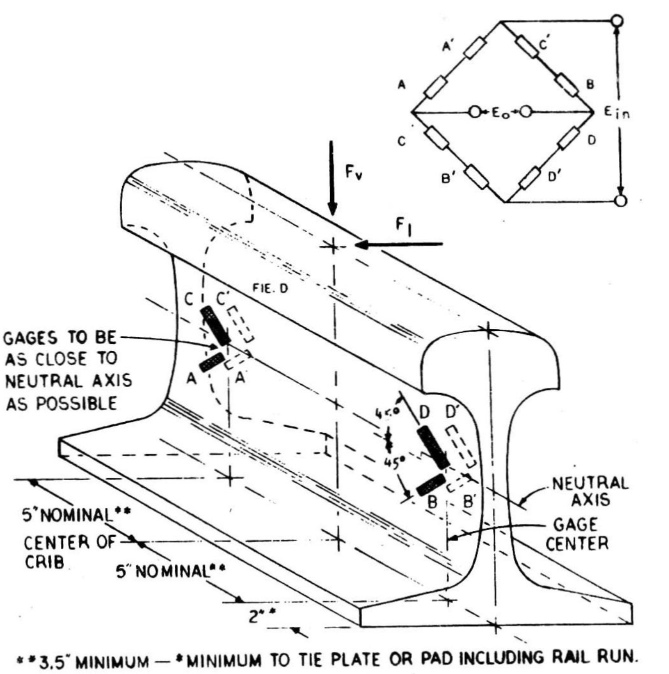


Fig. 5 - Battelle web chevron vertical force circuit

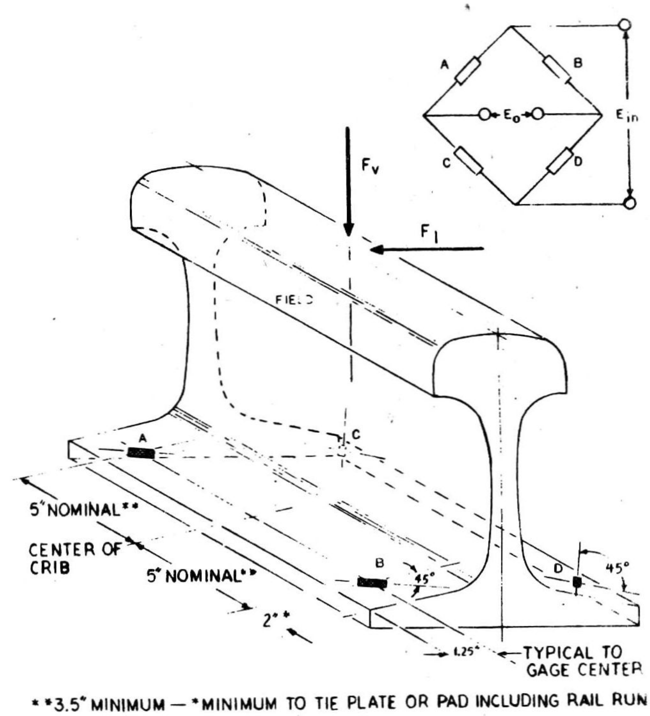


Fig. 6 - Battelle chevron lateral force circuit

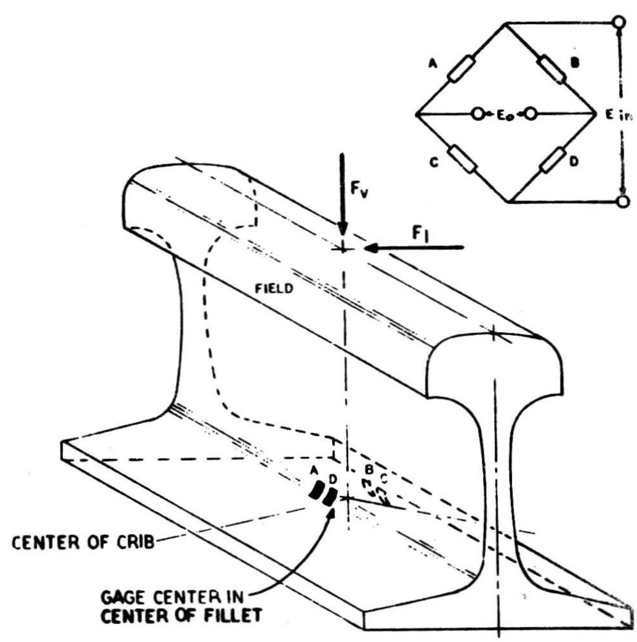


Fig. 7 - Web base fillet lateral force circuit

day. In most cases, only one gage of an eight-gage circuit failed in one day. After half the circuits had failed, the Ailtech portion of the test was terminated and the manufacturer was allowed to remove samples for evaluation.

BLH Results

BLH gages were not installed due to the difficulty of attaching lead wires.

TABLE 1--GAGES EVALUATED IN THE DURABILITY TEST

Gage	Quantity	Mfg.	Type	Part Number	Figure No.	Cost Per Element
*1	16	Ailtech	Heavy Duty	SG-129-6S/18	8	$ 35
2	16	Ailtech	Revised H.D.	SG-129-6S/19	8, 9	35
3	8	Ailtech	Chevron H.D.	RG-129-6S/18	10, 9	?
4	2	Ailtech	Dual Element	SG-329-6S/12	8	?
*5	0	BLH	Standard 1/4"	FSMW-25-35-SG	11	#14
6	0	BLH	Standard 1/2"	FNW-6-50-12	11	#14
*7	6	Brewer	Standard	BWG-6-1255-35-1	12	50
8	7	Brewer	Chevron	BWG-6-125V-35-1	12, 13, 14	50
*9	24	Hitec	Standard	HBW-35-125-6-10-GP	15, 16	35
10	4	Hitec	Chevron	HBW-35C-125-6-10-GP	16, 17	29
11	4	Hitec	Shear	HBW-S-35-125-6-3VR	18, 19, 20	18
*12	16	Micro-Measurements	Standard + Lead	CEA-06-W250A-120 OPT. B 290	20, 21	#18

*Original five gages

#Includes $2.50 for environmental protection kit

TABLE 2--GAGES EVALUATED FOR PERFORMANCE

Gage	Quantity	Mfg.	Type	Part Number	Figure No.	Cost Per Element
9	12	Hitec	Standard	HBW-35-125-6-10-GP	15, 16	$ 35
11	8	Hitec	Shear	HBW-S-35-125-6-3VR	18, 19	18
13	8	Brewer	Stacked Chevron	BWG-6-125SV-35-1	22, 14	50

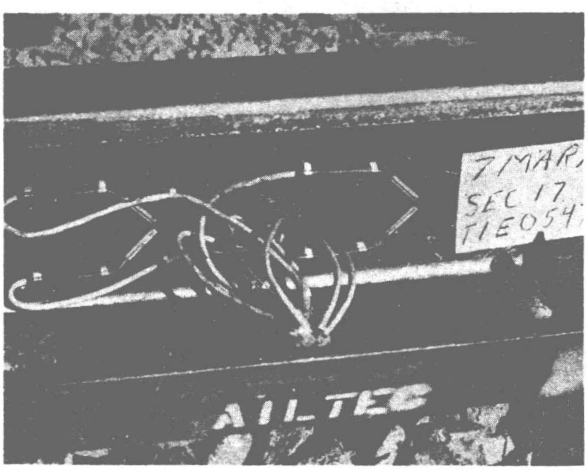


Fig. 8 - Ailtech heavy duty gage

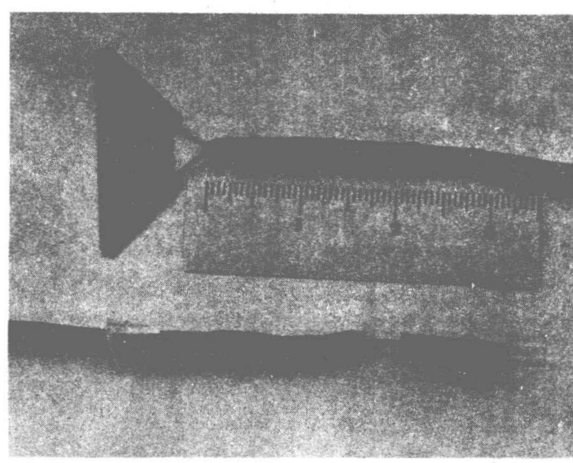


Fig. 9 - Ailtech chevron and standard gages

BREWER RESULTS

Brewer gages were subjected to over 955,000 cycles of strain without any failures. Installation ease was rated at medium due to the large area that has to be prepared for welding.

HITEC RESULTS

Hitec gages were subjected to over 955,000 cycles of strain without failure. Installation ease was rated at low for the individual gages because they required a large area to be prepared and eight gages (instead of four) had to be alined.

The chevron gage installation ease was rated at medium because of the large area to be prepared.

The shear gage was rated high on ease of

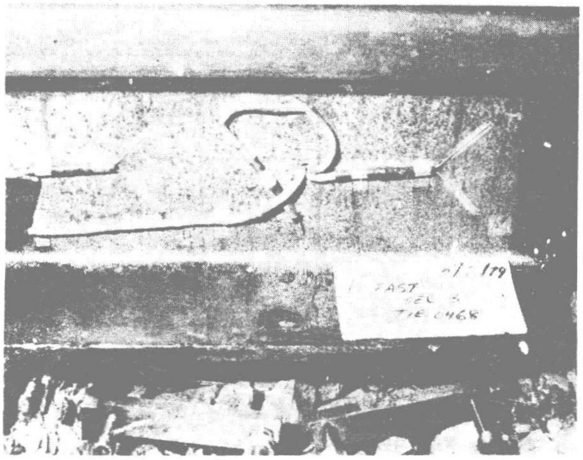


Fig. 10 - Ailtech chevron gage

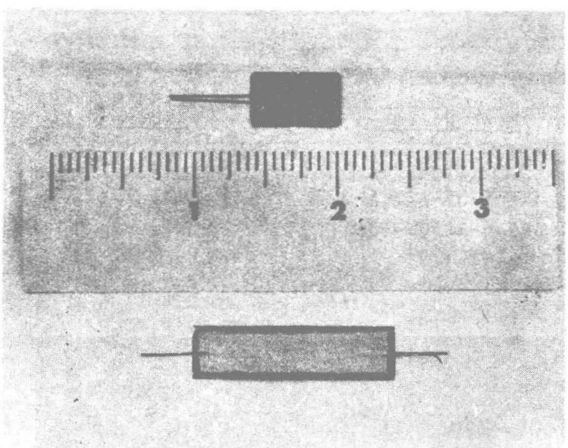


Fig. 11 - BLH gages

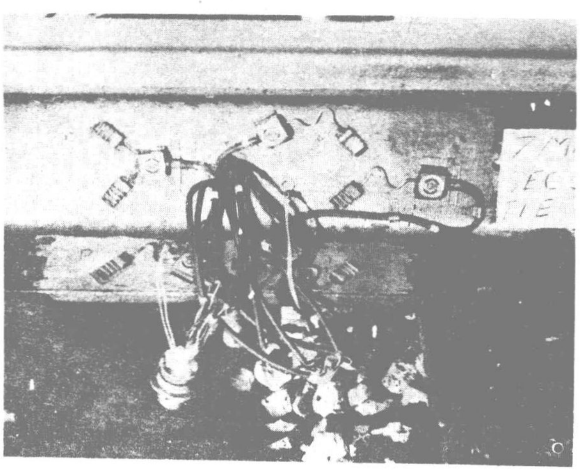


Fig. 12 - Brewer standard and chevron gages

Fig. 13 - Brewer second generation chevron gage

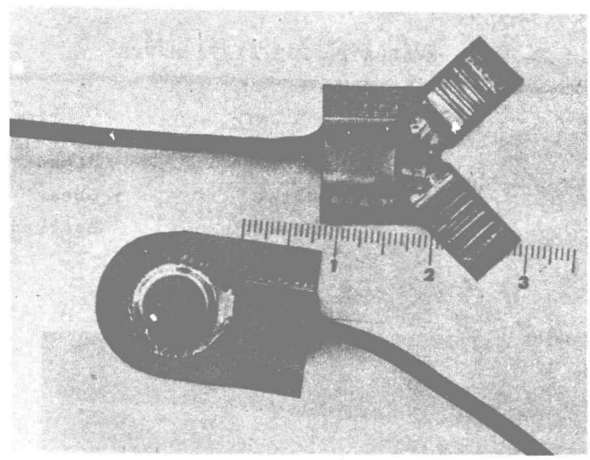


Fig. 14 - Brewer chevron and stacked chevron gages

Fig. 15 - Hitec individual gage

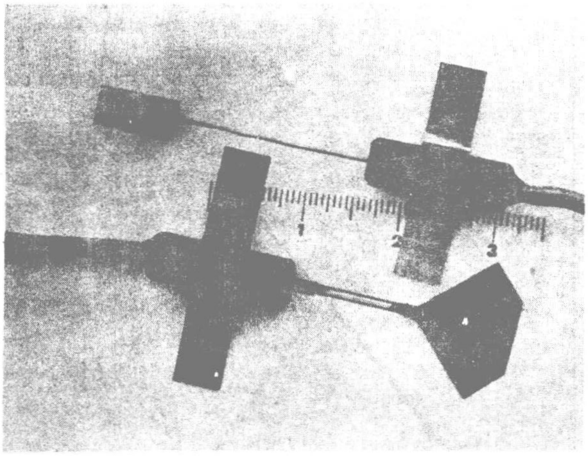


Fig. 16 - Hitec individual and chevron gages

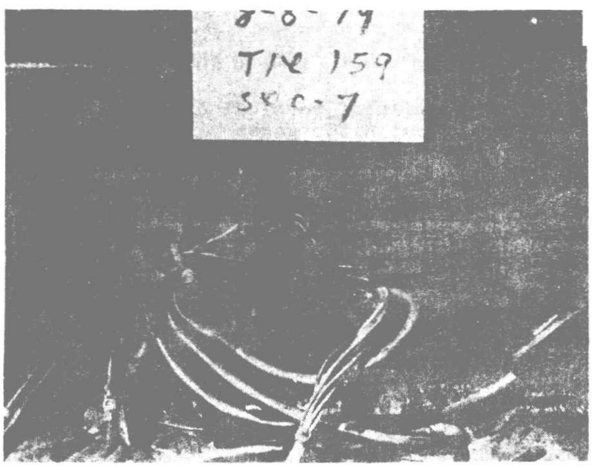


Fig. 17 - Hitec chevron and individual gage

Fig. 18 - Hitech prototype shear and Brewer double fillet gages

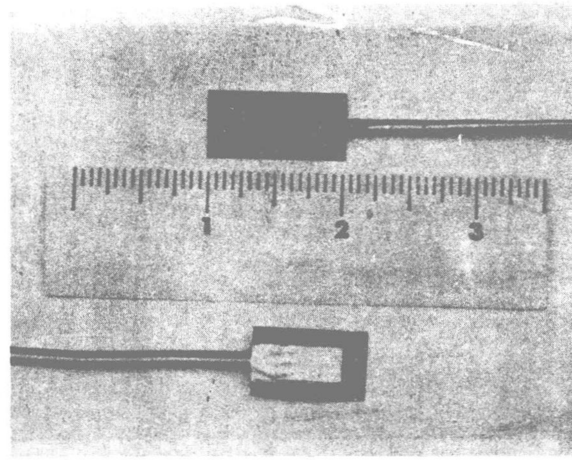


Fig. 19 - Hitec prototype and production gages

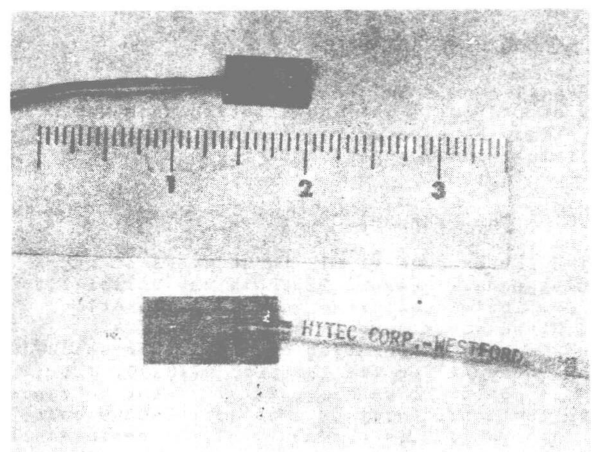


Fig. 20 - Micro-Measurements gage and Hitec demonstration gage

Fig. 21 - Micro-Measurements gage

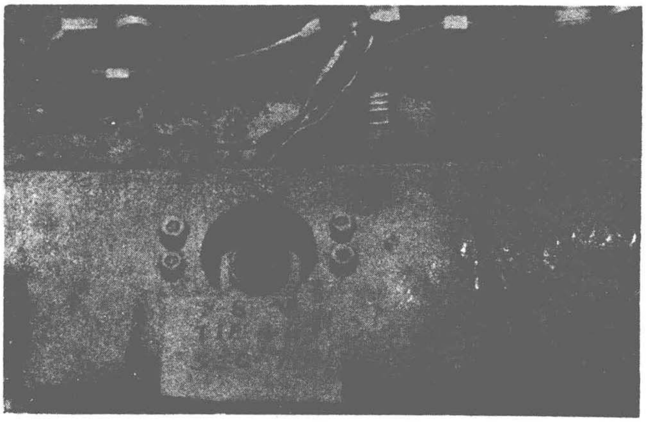


Fig. 22 - Brewer stacked chevron gage

installation because of the small area required and less welding. This gage also was one of the lowest in cost.

MICRO-MEASUREMENTS RESULTS

None of the gages failed during the 955,000 cycles of testing. The installation ease was rated at low because extra time was required to install individual gages and apply the environmental protection.

RESULTS OF THE PERFORMANCE TEST

The performance of all three types of gages was about equal. Figure 23 shows the calibration curve for individual Hitec gages. Calibration of the Hitec shear gage is shown in Fig 24. Figure 25 shows calibration of the Brewer stacked chevron. Except for tie location 07-0399, all gages had about the same sensitivity, but no cause for the low sensitivity of location 07-0399 could be found. Table 3 is a summary of the performance test.

RESULTS OF LATERAL CIRCUIT

Figure 26 shows the excessive crosstalk obtained in some base chevron circuit (Fig 4) locations with the Hitec individual weldable strain gages. Other gages were about equally responsive; however, there was considerable variation from location to location. Figure 27 shows the calibration obtained using individual Hitec gages in the base fillet circuit shown in Fig 7. This circuit had less output and more hysteresis than average, but usually had less crosstalk than the base chevron circuit of Fig 6. The base fillet circuit has the possible advantage of using only two double gages, thus further minimizing the installation time.

SUMMARY

All foil type weldable strain gages tested survived approximately one million cycles of strain in the test installations on the FAST Track. No difference could be detected between wood and concrete tie sections of track in the failure of the Ailtech weldable strain gages. The performance in the vertical load measuring circuit of the three types of gages evaluated was the same; therefore, installation ease and cost become the deciding factors in choosing gages. Because of its ease of installation and low cost, the Hitec shear gage with vinyl ribbon lead was selected for future use. We plan a future performance evaluation test to try to optimize the lateral circuit for cost, linearity, and crosstalk.

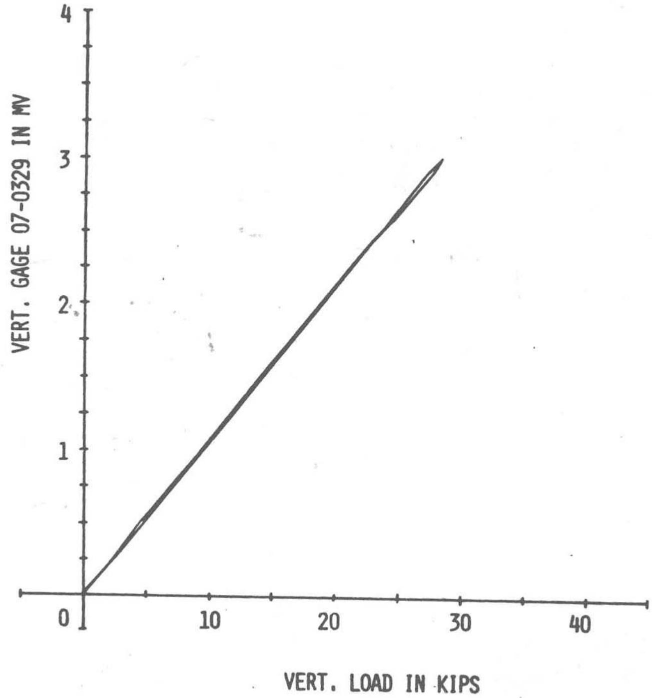


Fig. 23 - Calibration of vertical circuit with individual Hitec gages

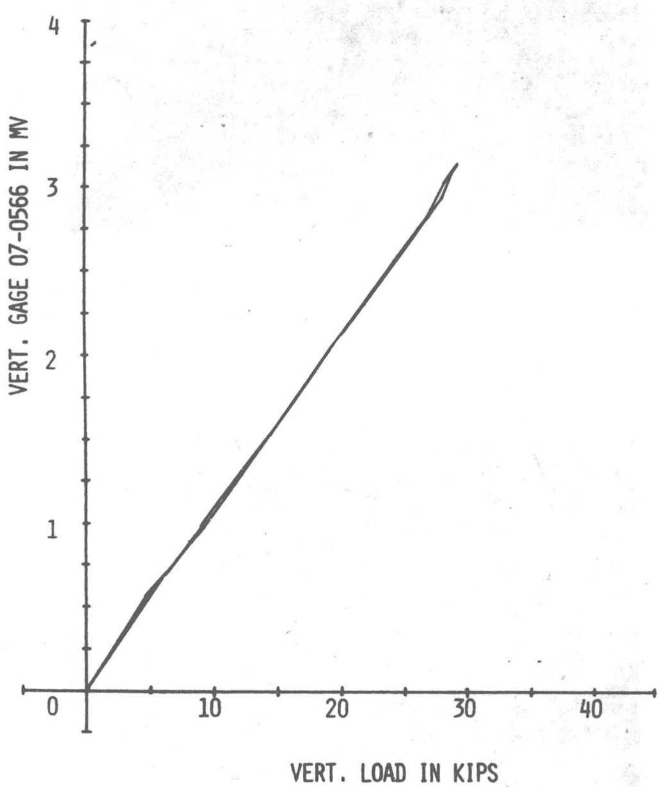


Fig. 24 - Calibration of vertical circuit with Hitec shear gages

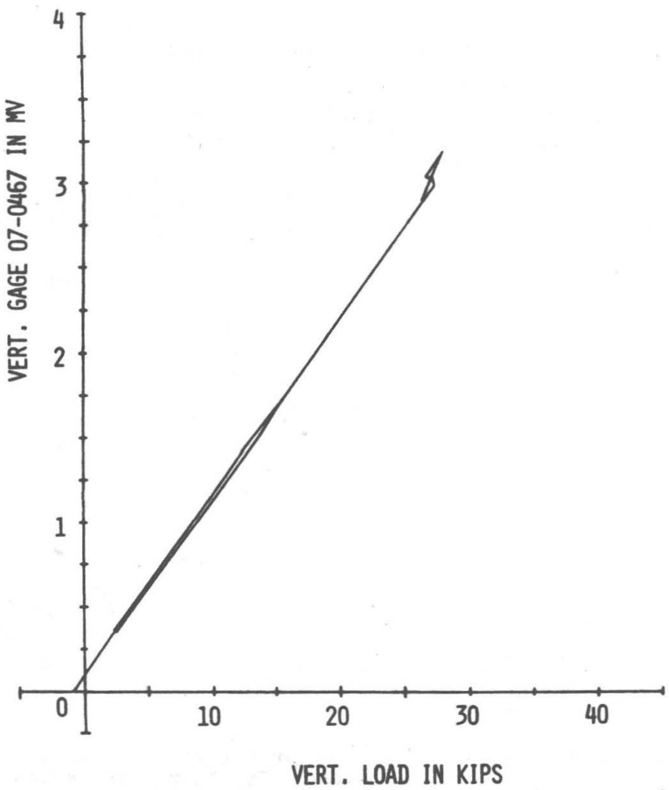


Fig. 25 - Calibration of vertical circuit with Brewer stacked chevron gages

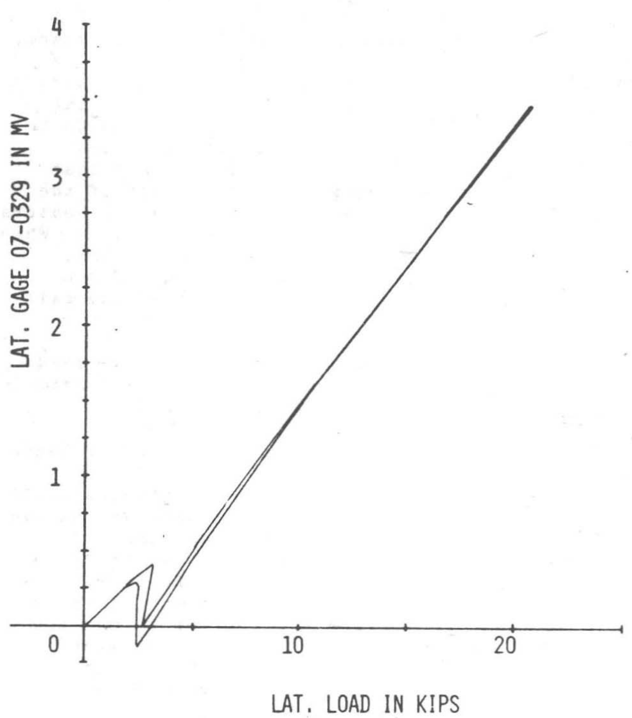


Fig. 26 - Calibration of base lateral circuit with Hitec gages

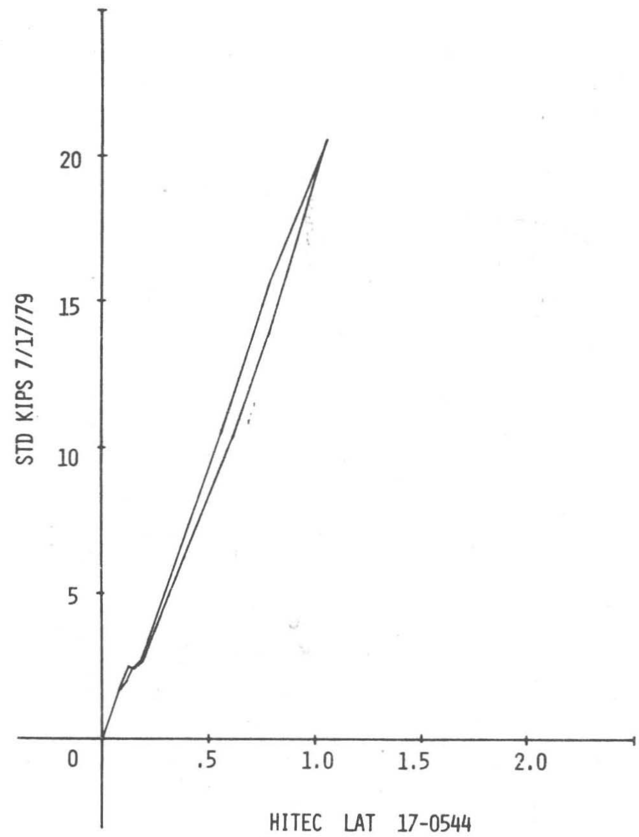


Fig. 27 - Calibration of fillet lateral circuit with individual Hitec gages

NOTICE

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this paper.

DISCUSSION

QUESTION: First of all, I did not understand your tonnage load on the rail. I do not understand the units. Another question I have is on the failure of your AilTech gages, do you feel it was a problem in the gage or in your installation? I have a feeling it was in the installation.

SPEAKER: Back to the million gross tons. You take a piece of track--that is how many millions of gross tons that have been rolled across that one station. In other words, if you take a 100-ton car and roll it over there enough times, you will get a million gross tons that have rolled across that section of track. That is a common railroad term they use to define how much traffic has been on a track. You have to know the weight of the train to get that. As far as the installation, we went around and around with AilTech many times on this installation of the gages. Back in the early tests, when we first had the failures and started mounting them with the Micro-Measurements in there, that was the AilTech comment at that time. It was an installation problem, and so we sent people to their schools to try to get better training. They had done

TABLE 3--PERFORMANCE TEST RESULTS VERTICAL CIRCUIT

Tie Location	Gage Type	Fastener	With 0-0.25k Lateral Load (mV/k)	With 0-20k Lateral Load (mV/k)	Gage Spacing (in)	% Change
07-0566	Shear	Forster Clip/German K-Plate	0.10551	0.10610	9 1/8	+ 0.56
07-0517	Shear	Wedge Fastener/Hixion Wedge Plate	0-10179	0.10373	7 3/4	+ 1.91
07-0467	Stack Chevron	Cut Spike (2F, 2G)	0.10508	0.10814	10 1/2	+ 2.91
07-0399	Stack Chevron	Fortex	0.08820	0.08998	8 1/4	+ 2.02
07-0329	Individual	Double Cluster Clip	0.10588	0.10585	8 1/2	- 0.03

an analysis on some of the earlier gage failures which I did not include here. It turned out it was fatigue that had caused most of the failures in that particular set of gages. They came out also to give us some special instruction in how to attach these leadwires down. They welded some down in the plant like they felt they should be welded down, after about a day of everybody playing with these gages trying to see how stiff they were so we could check ours, their gages came loose, on the lead wires. And it turns out that when you put the U-clamp over that leadwire, there is no way to weld it down tight. That could be part of the problem, but we felt it was an installation problem with the gages, not with our techniques. It took such fancy fastenings or whatever, that there was no way in the field we could control welding them down tight enough. AilTech has enough representatives here that they might want to make some more comments on these failures. Do you have any other comments, and then we will give them a chance?

QUESTION: Yes. In your curves was that millivolts per volt or just millivolts--and what was your excitation?

SPEAKER: That was straight millivolts, and I believe they were all 10-V excitation.

QUESTION: About what stress and strain levels were you running those?

SPEAKER: We feel that around 250 microstrain is the peak stress at these loads. Now what the dynamic stresses get to, I have no idea.

COMMENT: I did talk to Larry about the installation itself. I think what we thought was most of the problem at the time was just the strapping of the junction area between the cable and the gage down to where it was stiff and actually following the rail and going up and down. We felt the cable going up and down was really giving a fatigue test of the smaller tube. Even though the tube did not always break, the leadwires inside were open. We did show him how we thought the best way to strap them down, but it may be that is just too big to take this vibration. The only thing that might help is that if we could use a smaller gage, which we have, the 126 type rather than a 129, which is the lower mass. And we may be able to strap that down securely enough that it does not move around. But we have not had a chance to have this tried.

QUESTION: Would it be feasible to strap that tube down directly rather than, or perhaps in addition to, strapping the cables?

ANSWER: Yes. I was noticing on some of these installations where you used butyl rubber, you went all over the tube and some of the junction area. That might have been adequate.

SPEAKER: One of the other failure modes with the AilTech gages was just a short as well as a break, too.

QUESTION: Could you comment on the feasibility of using bonded foil gages? Is it impossible or difficult?

SPEAKER: How are you going to heat up 136 lb/yd rail to sufficient temperatures when the temperature is 20° below zero? And cure that epoxy or whatever you glue it down with?

QUESTION: Do you have portable power?

SPEAKER: 5-kW or 10-kW generators, yes.

COMMENT: Use Eastman 910.

SPEAKER: We want these things to last for 2 years.

COMMENT: I was wondering why you did not support the lead with this neoprene rubber covering when you used the AilTech gages. It looks to me like in the highest vibration area that you needed protection in. Did you not heat the rail to get a good seal over most of the things? Heating the rail with infrared heaters or clamp-on heaters is not a big problem. When it is down to 20 below, I would not think, because it is isolated in that area if you have enough power. Did you not heat the rail to clean it?

SPEAKER: No, we did not heat the rails. We used spotwelders to weld these on, so they furnish their own heat in the localized area.

COMMENT: Not on the AilTech but on the other gages.

SPEAKER: The other gages all had preattached leadwires, also. And the other problem we had was we have not been able to keep any trained strain gage technicians working out there at the test center. We are using the lowest level technicians to put this on, and we felt that is another reason for not wanting to use the bondable gages. I have not had that much direct experience myself with it, but it is still somewhat of an art, and we have not been able to keep trained technicians around there long enough to be able to bond gages down. I also challenge anybody to bond the gage down in that environment in the time we can spotweld one down.

QUESTION: In the area to which you did apply these, was it precleaned before you attempted to weld to that?

SPEAKER: We take a grinder, grind the rail clean, and then sand it smooth to weld it on. As far as I know, other than that one Brewer gage in the fillet that I mentioned, we have not had any trouble with bonding of the spot-welding. We have pulled these gages off and the spot-welds all check pretty well. I have some Brewer gages even that we have pulled off where it pulled the weld apart.

COMMENT: The Brewer gage was a copy of a gage another fellow and I developed; he had outside experience. And I think it is even superior to theirs. But that is just a personal opinion.

QUESTION: You showed some accelerometer measurements showing power spectral density. The lateral one was quite high, 0.1 g^2/Hz. Did you actually get any strain-gage data analyzed on the spectral analyzer?

SPEAKER: No. For one thing, the gage length tends to be long. For the AilTech gages it is 1 inch long and even these Hitec gages are about an inch long welded down. We have never really tried to look at the high-frequency output of the gages.

COMMENT: It seems to me that may be a problem in the sense that you are measuring a static load of 250 microstrain. I have a feeling that the failures of the gages is a result of the dynamic strains. You may have entirely different strains that the gage is responding to.

SPEAKER: That acceleration data, as I mentioned, is highly questionable in itself. I just put it up there to give you some indications of what the problems might be. We have had trouble. The accelerometer that I mentioned that we had on there measured the vertical force. In preparing this paper I went back looking at calibration curves a bit trying to pick out a curve to put in here on longitudinal, and I found out that when we postcalibrated that accelerometer, it was destroyed. So we have had trouble destroying accelerometers also--in fact, we ran another test of those BBNs and destroyed the accelerometer on those. So it is a horrendous environment. There is a lot of work to do.

COMMENT: My feeling is that the dynamics of the mechanical problems are far more involved than the static measurements show. The conventional measurements you made with the gages statically are not the real answer.

SPEAKER: And even if you just take the wheel pack in which the cycles that I referred to in here are basically the number of wheels that go over and give you 250 microstrain. The number of this high-frequency cycles. You can stand out there with the train one-half mile away and hear the rails singing.

COMMENT: That is what I think is happening. It is responding to something dynamic like that.

COMMENT: I personally have installed very many AilTech and Microdot clear back the last 20 years, and I have never experienced this problem as long as I backed the welding strap up with some RTV, or butyl rubber, or something of that nature.

SPEAKER: Yes. Originally we tried to put these down with RTV, and we had trouble with getting the rail contaminated. The RTV did not bond to the rail, and that was one of AilTech's original comments. The whole leadwire came loose, and there was no question that we had it poorly attached.

COMMENT: There are RTVs for which you do not need a primer. As long as you have the weld there to speed up production, put the butyl rubber or whatever you are going to do on it, I am sure that failure would not have occurred.

COMMENT: Some years ago AilTech or Microdot, or whatever the name was, made weldable gages. But rather than having that big bulky transition they had a 10-ft tube with a leadwire of magnesium oxide packed right out of it.

SPEAKER: I think they still make that. They also make it with this final ribbon that we are actually using on the shear gage. We did not actually try any of those, but with this new angle-iron covers we could probably use some. But we have spent so much money arguing and testing AilTech gages that our viewpoint right now is that we have got a gage that works, and we are not going to test any more gages for AilTech.

ENGINEERING MANAGEMENT OF A RELIABILITY PROGRAM

By

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I wish that I had prepared something on vibration techniques and AilTech strain gages after I listened to Larry. He did assure me on the phone a week or so ago that he was going to make a very brief comment on AilTech gage failures, and I noted that that was fairly widely discussed. And I do not have too much to say about that. Except the whole business of testing and of maintaining reliability for anyone's product begins at the factory and in the engineering group. Then it is translated into effective action through the production group before it gets outside the factory. AilTech, as with many other manufacturers, has suffered difficulties, problems, and occasionally misunderstandings at the customer level. It points up the need for us to be more conscious of our customer's needs and the need for us to maintain a high level of reliability within our own plant. That is what I had planned to talk about this morning, was approaching a reliability program from the standpoint of the engineering department. I really want to share with you our approach to the management of a high-reliability program. We were asked 6 or 10 months ago to become involved in a program designed for overseas applications. Some of the experiences we had with this approach have reinforced for us that starting from engineering management is probably a good position. I will outline for you a particular program that I am using for reference and how it appeared to us at its beginning. We were asked by our customer to supply strain gages for what could become a fairly hostile environment. Second, we were asked that these gages meet a set of requirements that our customer defined, and that the raw materials and assorted products that would go along with the gages would all meet the same requirements. Our customer requested that we establish an overall test and performance criteria, and develop documentation specifically designed for their order. This documentation included a fairly elaborate comprehensive pretest, prequalification program for those manufacturing operations that were unique to the customer. Now those manufacturing operations that were unique to that customer were also unique to AilTech. So we were in the position of developing documentation and testing programs on some processes that we had very little experience on. We were asked to design, write, and implement the support documentation product-performance specs, manufacturing test plans, and traveler control systems. So we were in control of the operation through each step of the process.