

BEFORE THE  
UNITED STATES DEPARTMENT OF TRANSPORTATION  
FEDERAL RAILROAD ADMINISTRATION

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PUBLIC HEARING ON  
DOT DMS DOCKET No. FRA-2006-26175, NOTICE No. 1  
OCTOBER 19, 2007

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TESTIMONY OF  
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BROTHERHOOD OF LOCOMOTIVE ENGINEERS AND TRAINMEN,  
A DIVISION OF THE RAIL CONFERENCE  
OF THE INTERNATIONAL BROTHERHOOD OF TEAMSTERS



**Before the  
United States Department of Transportation  
Federal Railroad Administration  
Public Hearing on  
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October 19, 2007  
Testimony of  
Thomas A. Pontolillo, Director of Regulatory Affairs  
Brotherhood of Locomotive Engineers and Trainmen**

Good morning and thank you, Mr. Chairman. I'm Tom Pontolillo, Director of Regulatory Affairs for the Brotherhood of Locomotive Engineers and Trainmen, which is a Division of the Teamsters Rail Conference. I appear today on behalf of more than 33,000 active BLET members, most of whom will be significantly impacted by this rulemaking. We appreciate the opportunity to be heard on this important subject.

I want to begin by apologizing for the length of today's presentation. The Proposed Rule and the documents already in the docket cover many complex subjects and I simply cannot gloss over them, given their importance to my membership. I also am certain that I will say many of the same things that my Labor Brethren will say, and that's because we have shared concerns that cross craft lines.

At the hearing two weeks ago, I noted that our review and consideration of the proposed rule and the documents in the docket were guided by two basic principles, both of which are worth reiterating briefly here. The first is the recognition that implementation of ECP will occur on an incremental scale and, therefore, we believe ECP brake rules should include standards different from current Part 232 requirements only when absolutely necessary from an operational standpoint.

The second principle is that different standards are appropriate only when (1) necessary in order to foster the broad application of ECP technology, (2) the current standard is so prescriptive that compliance is impossible; and (3) the current standard is inapplicable to the new technology, given the way that ECP operates. This analysis distinguishes alternative standards that are operationally necessary from those that are merely operationally convenient.

My comments today are divided into three general areas. First, I will address the four general questions posed by FRA in its hearing notice. Next, I will comment on a number of provisions in the proposed rule, and set forth our views both on FRA's proposed standards and on alternatives that we believe promote a higher, and necessary degree of safety. Lastly, I will turn to some of the other documents in the docket and either comment on them or raise concerns about certain aspects of proposed standards.

Because it is likely that responses to questions and issues I raise today may not be provided until the Technical Conference later today, I would add two caveats. One is that the lack of comment on my part concerning a specific proposed regulation or standard should not be

taken as BLET support for that regulation or standard. The other is that we reserve the right to supplement these comments based upon what additional information we gain today.

### FRA's General Questions

The first general question FRA seeks comment on is whether “allowing an ECP braked train with defective brakes to travel to its destination, not to exceed 3,500 miles, [will] decrease, maintain, or exceed the level of safety provided for a conventional pneumatic braked train receiving a Class 1A brake inspections every 1,000 miles?” 72 FR 50828. In this regard, we would point out that FRA states as follows:

FRA believes that an ECP brake operated freight train may travel nonstop to its destination, not to exceed 3,500 miles, because foundation brake rigging and brake shoes will safely operate over this distance and redundant intermediate brake inspections for an ECP brake operated train moving that distance do not increase ECP brake system safety. As an added benefit, the increased mileage allowance would provide for coast-to-coast travel. In the related proceeding, Docket No. FRA-2006-26435, FRA's Safety Board granted the request of BNSF and NS to allow the non-stop movement of an ECP brake operated train to its destination, each not to exceed 3,500 miles. FRA believes that the proposed rule should codify this regulatory relief so that it applies universally.

#### Id.

Unfortunately, it appears to us that FRA already has answered this question, at least to its own satisfaction. In our post-hearing comments in the BNSF/NS waiver matter, we opposed granting relief from the 49 CFR Section 232.207 requirements pertaining to Class IA brake tests, as well as relief from the 3,000 mile limit applicable to cycle trains. *See* FRA-2006-26435-17 at pp. 9, 12. Our position was premised on the facts that: (1) relief was not operationally necessary; (2) the ECP monitoring system does not convey all of the information gleaned from the inspection; and (3) different standards for different equipment sets that will be operated side-by-side that are not operationally required provide a recipe for confusion and introduce unnecessary risk. Id.

In granting the waiver in that matter, FRA

decided that, in order to *demonstrate* the safety and efficacy of ECP brakes in a practical commercial setting, it is necessary to permit a train operating in ECP brake mode to operate to its destination or 3,500 miles, whichever is less, without receiving another Class I brake inspection or an inspection under Part 215. As a practical matter, railroads are most likely to use ECP brakes first on such trains as intermodal trains from West Coast ports to Chicago or unit coal trains from the Powder River Basin to distant power plants. A valid demonstration of the technology should address that reality, and this waiver does so with appropriate safeguards intended to ensure that these trains will be as safe as trains operated without benefit of the waiver, *while collecting data on the demonstration to be used in FRA's pending rulemaking* on ECP brakes.

FRA-2006-26435-18 at p. 2 (emphasis added).

As we know, ECP braking had not been implemented in the service covered by the BNSF/NS waiver at the time the proposed rule was published. Indeed, we were told at the hearing in Washington two weeks ago that implementation was imminent. Consequently, that waiver has not yet produced any data upon which FRA can rely in this rulemaking. The mere expectation that “foundation brake rigging and brake shoes will safely operate over” 3,500 miles is insufficient justification for FRA to take a temporary standard granted in a waiver for purposes of gathering data and write it into the permanent rule when none of the data has been gathered, much less analyzed and subjected to public scrutiny and comment.

We also would point out that the 49 CFR Section 232.205(a)(4) standard of 3,000 miles between Class I brake tests for unit and cycle trains is now over 5½ years old. Frankly, we are puzzled that no data has been introduced in this docket establishing if, and how frequently, foundation brake rigging, brake shoe, or Part 215 defects are found. It seems to us that either FRA or the industry should be able to back up a claim concerning the reliability of foundation brake rigging and/or brake shoes — at least up to 3,000 miles — by pointing to data gathered for unit and cycle trains. That no such empirical evidence has been produced leaves us in the same position today as we were when FRA was considering the BNSF/NS waiver. Needless to say, unpersuaded as we are with respect to a 3,500 mile limit, we also are strongly opposed to the 5,000 mile limit proposed by Mr. Maryott at the hearing two weeks ago.

The second general question posed by FRA pertains to what safety hazards, if any, will be caused by switching an ECP-braked car into a technologically incompatible train equipped with conventional pneumatic brakes. 72 FR 50828. If the ECP car is equipped with either an overlay ECP brake system or an emulator car control device (“CCD”), we believe there will be no safety hazard whatsoever. On the other hand, if the ECP car is equipped with only a stand-alone CCD, then there is a risk. However, in our view the risk is no greater than that presented by a conventionally-braked car with inoperative brakes. That risk can be neutralized by restricting the defective ECP car in a manner identical to the restrictions imposed upon a conventionally-braked car with inoperative brakes.

The third general question is whether it is safer for an ECP braked car with defective non-brake parts to be switched into a train equipped with conventional pneumatic brakes — rendering the switched car’s ECP brakes ineffective — for backhauling to the nearest repair station, or allowing it to continue to the nearest forward repair location in the ECP brake equipped train with more than 85 percent effective and operative brakes. *Id.* If the ECP car is equipped with either an overlay ECP brake system or an emulator CCD, there is no question that it is safer to switch out the car for backhauling.

If the ECP car is equipped with only a stand-alone CCD, we believe that, on balance, it still is safer to switch out the car for backhauling. Because this hypothetical does not detail the nature of the defect, it is impossible to ascertain the risk of continued forward movement with a great degree of certainty. Thus, the question in this instance presents only two realistic options. The first would be to detail the various types of defects that would fit the hypothetical and craft the rule around each defect; however, this would be overly prescriptive, in our view, and could prove unworkable. The other option would be “take the safest course” — as we were taught

beginning on our first day in the industry — and opt to switch out the defective car for backhauling.

The fourth general question asks whether 49 USC Section 20303 provides a disincentive sufficient to preclude implementation of ECP brake technology. Id. We believe that there is no such disincentive, for two reasons. First, S. 1889, the Senate’s version of the rail safety reauthorization bill, would change the definition of “nearest” to limit it to the forward direction of the train, which is the same relief the industry seeks here. If this change is enacted as law, FRA’s question becomes moot. Second, assuming that the statutory definition of “nearest” remains unchanged, the limitation on movement applies irrespective of car type, defect, or technology. Thus, a defective car equipped with an ECP brake is not treated less favorably than a defective car equipped with conventional pneumatic brakes. In this circumstance, we can see no disincentive whatsoever.

### **Preamble Section X**

Before turning to the specific provisions of the proposed rule, I first want to address several additional issues raised in the Preamble. In Section X.A FRA noted that, in the BNSF/NS ECP waiver matter, those carriers sought relief from Part 229 “daily locomotive inspections and electronic record keeping” requirements. 72 FR 50829. FRA further stated its belief “that there is insufficient information available to consider any exceptions to part 229 for operations using ECP brake systems” at this time, but, nonetheless, requested “comments and information relating to this issue.” Id. As we stated in the BNSF/NS matter, except for the ECP head-end unit (“HEU”) and its associated appurtenances and displays, a locomotive equipped for ECP operations is indistinguishable from a locomotive equipped for conventional pneumatic braking operations. Thus, there is absolutely no basis whatsoever for relief from either the daily inspection requirements or the recordkeeping requirements of Part 229.

FRA also is right on target in Section X.B with respect to the relief sought in that matter by BNSF pertaining to the dynamic brake requirements contained in 49 CFR Part 232. Id. Section 232.109 provides for the continued operation of a locomotive found with inoperative dynamic brakes for a period of up to 30 calendar days, which is more than sufficient relief, and FRA is correct that more flexibility in this area is not necessary. Indeed, given that FRA proposes expanding the inspection interval to 3,500 miles and further proposes to allow trains with up to 5% defective brakes to leave the initial terminal, we believe it would be unwise and unsafe to further erode a train’s braking capacity by diluting dynamic brake requirements.

With regard to the Preamble Section X.C. treatment of single car air brake — or “SCAB” — tests (72 FR 50829), we believe the Final Rule should modify Section 232.17 to make clear the applicability of proposed Subpart G, including, but not limited to, adding cross-references. Further, we support amending Section 232.305(a) as indicated in the Preamble. We will comment further on appropriate SCAB test standards in our review of proposed Section 232.611(b).

Preamble Section X.D addresses the train handling information requirements of Section 232.111. Id. FRA states that “[t]he continuous monitoring capabilities of ECP brake systems

provide information regarding the location of equipment with inoperative or cut out brakes.” Id. We would point out that, in our view, the continuous monitoring capability is not quite that robust. Section 3.5.4.2 of AAR Standard S-4260, establishing ECP brake and wire distributed power interoperability test procedures, notes that “CCDs with a low or missing battery are counted as inoperable, ***but may not be displayed as inoperable*** until the total inoperable reaches less than 90% with trainline power OFF, or less than 85% with trainline power ON, at which time a penalty brake application will be commanded.” See FRA-2006-26175-13 at p. 36 (emphasis added). In any event, none of the information provided by the system appears to satisfy the requirements of Section 232.111(b). We agree with FRA that there is no reason for excepting any portion of or provision contained in Section 232.111.

Preamble Section X.E discusses piston travel limits. 72 FR 50829. We concur with FRA’s proposal to incorporate the current, industry-wide waiver permitting piston travel limits to range from 6 to 9 inches by amending Sections 232.205(c)(5) and 232.303(c).

In Section X.F, FRA solicits comments on its proposal to delete Sections 232.213(a)(6) and (a)(7) because they “sunsetting” on April 1<sup>st</sup> of this year. Id. While it is true that FRA did not act to extend these provisions and, therefore, they no longer are in effect, we must state for the record our disappointment that the requirements were permitted to extinguish. Section 232.213(a)(6) required inbound inspections for extended haul trains, and Section 232.213(a)(7) required railroads to maintain a record of all defective, inoperative, or ineffective brakes and all conditions not in compliance with Parts 215 and 231 or discovered during train movement. It seems to us that — if a case was to be made for extending inspection intervals for ECP brakes based on the reliability of brake system components common to both ECP and conventional braking systems — it would have been made from data compiled during Section 232.213(a)(6) inspections and on Section 232.213(a)(7) records.

Finally, Section X.G raises the issue of ECP technology and passenger train operations, particularly Amtrak’s Auto Train. FRA notes that “Amtrak has previously employed overlay ECP braking on that train, and presumably would benefit from some additional flexibility with respect to the conduct of intermediate inspections.” Id. We submit that “additional flexibility with respect to the conduct of intermediate inspections” should not be the impetus for moving toward ECP technology in any railroad operation, much less a passenger operation. The improved braking ECP would bring to Auto Train operations would be much less dramatic than it will be for trains comprised of 100+ cars of coal or double stacks. Also, we have concerns regarding the following passage from the Preamble:

FRA may consider Part 238’s applicability to ECP brake systems in another rulemaking or in other proceedings. If comments appropriate to this rulemaking are submitted, FRA reserves the right to include provisions addressing those issues at the final rule stage. Further, FRA would consider requests for waivers relating to the regulation of freight trains and freight cars equipped with ECP brake systems for passenger trains on a case-by-case basis.

Id.

We agree that the issue of ECP and Part 238 should be addressed in a separate rulemaking. For this reason, we do not believe it is appropriate for FRA to regulate ECP on passenger trains via the waiver process on a case-by-case basis. Moreover, if FRA's reference to "comments appropriate to this rulemaking" includes ECP and Part 238, then we have a problem with FRA's reservation of rights to include provisions addressing those issues in the Final Rule. The entire focus of the proceeding thus far has been ECP freight operations. We ask FRA to clarify that it will not amend Part 238 in the Final Rule.

On a somewhat related issue, FRA notes that it "does not propose any rules uniquely regulating trains or cars equipped with emulation ECP brake systems," but "seeks comments on whether or how it should regulate such systems differently than what is proposed herein." 72 FR 50823. We believe that applicability of regulations should be predicated upon the type of braking technology being used. By that we mean that ECP regulations should apply when a car with an emulator CCD is used in an ECP-equipped train, and conventional Part 232 regulations should apply when that car is used in a conventional pneumatically-braked train.

### **Proposed Section 232.603**

Moving on to various provisions of the Proposed Rule, itself, we support FRA's concept — as set forth in Sections 232.603(a) and 232.603(f) — to utilize the Section 232.17 alternate standards and Section 232.207 modification procedures, respectively, in order to change incorporated industry standards. Regarding proposed Section 232.603(b), we do not oppose a requirement that all ECP brake systems receive **final** approval under AAR's S-4240 standard prior to use and that they maintain such approval while in use.

However, we believe that FRA's Railroad Safety Board should review petitions for conditional approval via the waiver process. The AAR standards incorporated by reference appear to be fairly stringent, and it seems to us that a system either meets those standards or it does not. In the former event, it should qualify for final approval. If the system does not qualify for final approval, the question of its deployment should specifically be decided by FRA.

In its section-by-section analysis of proposed Section 232.603(c), FRA discusses, at length, the issue of hardware and software configuration management plans. *See* 72 FR 50831. Simply stated, our position is that these plans should conform to the requirements of Part 236, Subpart H. There is a strong likelihood that the majority of the routes over which ECP will be deployed also will see the implementation of positive train control ("PTC"). Given the manner in which PTC will enforce speeds and authorities, the ECP head-end unit and its associated appurtenances will become a core element of the PTC system. We strongly agree with FRA that no train should be operated in ECP brake mode in revenue service unless it is using an ECP brake system that complies with a configuration management plan incorporated into the final rule or another configuration management plan otherwise approved by FRA.

We cannot support proposed Section 232.603(e), which would permit a party interested in using new ECP brake system technologies or using an ECP brake system technology not approved by AAR prior to the effective date of the Final Rule to file a written request with the FRA seeking an exception from Subpart F. Among other requirements alternative to Subpart F,

FRA proposes mandating that the testing or demonstration that will be conducted pursuant to an “FRA-recognized industry standard.” 72 FR 50832.

As FRA knows, in the related BNSF/NS waiver matter we objected to exempting the petitioners from the requirements of Subpart F. *See* FRA-2006-26435-17 at p. 3. We stated then — and we reiterate now — that the pre-revenue service acceptance testing plan requirements set forth in Subpart F provide data and other information that is necessary in order to safely regulate the technology. Moreover, FRA does not propose than an exception be granted if testing or demonstration is conducted pursuant to an AAR standard that has been *incorporated by reference*, after being subject to public review and comment. Rather, FRA proposes a lower requirement, that the testing/demonstration standard only be *FRA-recognized*.

### **Proposed Section 232.605**

Regarding Section 232.605, we suggest two enhancements that would strengthen the training required by the Proposed Rule. First, we strongly believe that all training programs should be submitted to FRA for approval.<sup>1</sup> In our view, appropriate training must include not only the relevant federal regulations applicable to the particular craft of worker, it also must include the appropriate portions of the six (6) AAR standards incorporated by reference into the regulation as they pertain to the work of that craft. Stringent FRA oversight of training is necessary for this reason. Second, while we acknowledge the value of periodic assessment of training programs by railroads, FRA should clarify that it reserves the right to audit such programs when FRA determines is it appropriate to do so. We agree that it is vital for labor to be intrinsically involved in the assessment process, from beginning to end, and that evaluation of training techniques might best be approached through a “team” method, where several observers, including labor representatives, periodically evaluate course or “hands-on” training content and presentation. *See* 72 FR 50832.

### **Proposed Section 232.607**

Regarding proposed Section 232.607(a), we wholeheartedly concur that all Class I brake tests at initial terminals should be performed by a qualified mechanical inspector (“QMI”), and that that all of the mechanical inspections required to be performed on a train at its initial terminal should be conducted by an inspector designated pursuant to 49 CFR 215.11. *See* 72 FR 50833. In response to the industry objection to this requirement at the first public hearing, which later was clarified to pertain only to “short haul” movements of less than 1,000 miles, we believe the objection is without merit.

Under FRA’s proposal, this inspection and test serves as the basis for operating the train up to 3,500 miles without another inspection or test. Establishing two standards on the basis proposed by the industry will produce an oversight nightmare, because it will be very difficult, if not impossible, for anyone to track a particular car or block of cars to determine the qualifications of the various personnel who performed inspections and tests. In our view, what

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<sup>1</sup> Such approval already is required for ECP brake training that will be provided to Locomotive Engineers. *See, e.g.*, 49 CFR Part 40 at App. B.

the industry really seeks is the best of both worlds: long-distance runs without intermediate inspections and tests where it chooses, and operating ECP trains that have not been inspected by QMIs and Part 215-designated car inspectors in other circumstances.

Inasmuch as ECP is expected to be deployed on long-haul routes and for single-commodity trains — at least for the foreseeable future<sup>2</sup> — we do not believe the Final Rule should institutionalize the sort of “cherry picking” the industry proposes. If there is an anomalous situation, whereby cars are moved a very short distance from the point of loading and/or unloading to a staging area, for example, then the appropriate vehicle for relief from Section 232.607(a) is a petition for waiver from compliance, not a regulatory loophole. Moreover, we believe that in any case where the sort of additional relief requested at the first public hearing is granted, it should be required that the movement be made in the “Switch” mode of ECP.

I already have stated our position concerning the 3,500-mile distance between Class I brake tests and Part 215 inspections, which is addressed in proposed Section 232.607(b), so I won't repeat myself here. Moving on to proposed Section 232.607(c), we disagree with FRA's rationale. First, we oppose changing the Class I re-test requirement for trains “off air” from 4 hours to 24 hours. As we pointed out in the related BNSF/NS ECP waiver matter, the purposes for which a re-test is required when a train has been off air for more than four hours are not eliminated simply because a train is ECP-equipped. *See* FRA-2006-26435-17 at p. 8. We also oppose FRA's proposal that these re-tests need only be performed by a qualified person, rather than a QMI. And we reject FRA's rationale that requiring a QMI perform the re-test may provide a significant disincentive for a railroad to equip its trains with ECP brake systems. *See* 72 FR 50834. In our view, any conflict between safer operations and economic disincentives should be resolved in favor of safety, except where there is a substantial disparity in the balancing of the two interests.

Proposed Section 232.607(d)(1) generally parallels the Section 232.205(b) treatment of cars added to a train. Notwithstanding our objections to the 3,500-mile distance standard and the 24 hour “off-air” provision, this subsection appears to provide a level of safety equivalent to Section 232.205(b). Proposed Section 232.607(d)(2) addresses the placement of cars not equipped with an ECP brake system in an ECP-equipped train. In this regard, FRA has solicited

comments and information on what requirements may be necessary to safely allow the addition of cars equipped with conventional pneumatic brakes into an ECP brake equipped train, including, but not limited to, the placement and securement of cables along cars equipped with conventional pneumatic brakes to preserve their continuity between non-consecutive cars equipped with ECP brakes and the appropriate placement in the consist of cars equipped with conventional pneumatic brakes.

72 FR 50835.

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<sup>2</sup> We concur with FRA's assumption that “initial 10-year implementation will occur only on unit and unit-like train service ... include[ing] the following commodities: coal, grain, intermodal containers, motor vehicle parts, ore, and non-metallic minerals.” *See* FRA-2006-26175-16 at p. 7.

With respect to the placement of such cars, we believe that Section 232.15(e) would apply. There should be no question that the brakes on conventional pneumatically-braked cars in an ECP-equipped train are “inoperative” while that train is operated in ECP mode. They would be operative only if (1) the train was equipped with a dual mode ECP system and (2) the train is operated in conventional mode. In this circumstance, we would support permitting the railroad to opt to continue movement in that mode, provided the train otherwise meets all Part 232 requirements for conventional brake operations. Concerning placement and securement of cables along cars equipped with conventional pneumatic brakes, it is our opinion that current standards for securement of lading provide an appropriate reference. Further, we urge FRA to adopt a standard similar to that set forth in Section 229.89(a), which requires that jumpers and cable connections between locomotives shall be located and guarded to provide sufficient vertical clearance.

In its section-by-section analysis of proposed Section 232.607(f), FRA seeks comment on three issues. First, the appropriate way to replace the existing brake pipe service reductions and increases with an alternative requirement for an electronic signal that provides an equivalent application or release of the brakes during brake tests. Second, how the existing regulatory brake pipe leakage limits should be modified, if at all, for ECP brakes and whether changes in the leakage requirements will affect the pneumatic backup capability of the ECP brake system. And, third, the need to include the specific electronic reduction that is to be made on ECP-equipped trains during the required brake tests and what type of electronic signals would be suitable equivalents to the currently mandated 20-psi and 15-psi brake reduction. 72 FR 50836.

According to Section 4.2.5.2.1 of AAR’s S-4200 Standard, ECP head-end unit train brake commands are expressed as a percentage, with 0% representing that the brakes are released, 10% representing a minimum service reduction, and 100% representing a full service reduction. *See* FRA-2006-26175-7 at p. 22. Further, braking commands can be given in 1% increments, and 120% represents an emergency application. *Id.* With respect to the first and third issues raised by FRA concerning this subsection, we believe the appropriate alternative would be one that correlates a particular psi reduction with its digital percentage equivalent.

Our understanding of how the CCD operates is that it translates the percentage reduction signal in calculating the brake cylinder pressure to order. For example, with a 90 psi brake pipe in a conventional train, a full service reduction is approximately 26 psi, which produces a brake cylinder pressure of approximately 65 psi. Presumably, this is the brake cylinder pressure the CCD would order in response to a 100% train brake command. A 20 psi reduction represents approximately 76.9% of a full service reduction; assuming the train brake command scale is relatively linear, it seems to us that a 77% train brake command should replicate a 20 psi reduction. Similarly, a 15 psi reduction represents approximately 57.7% of a full service reduction, and a 58% train brake command should replicate a 15% reduction.

Even if the train brake command scale is not linear, it certainly should be consistent enough to develop percentages that accurately replicate the currently-mandated 20 psi and 15 psi requirements. Moreover, we strongly urge FRA to include in the Final Rule the precise percentages that are to be utilized in conducting required brake tests. Locomotive Engineers should be entitled to the same level of information pertaining to their compliance with FRA

regulations as they relate to ECP brakes as they currently enjoy for conventional pneumatic brakes, especially because misapplication of Part 232 requirements could lead to revocation of certification and/or individual liability for a civil penalty. *See* 49 CFR §§ 240.117(e)(3) and 240.305(a)(3).

Regarding brake pipe leakage, we strongly urge FRA to retain current regulatory limits. While FRA is correct that the brake pipe's use in an ECP brake train normally will be limited to charging brake air reservoirs when a train is operated in ECP mode, both the overlay and the emulator types of ECP technology also permit conventional pneumatic operations. Furthermore, Section 3.8 of AAR's S-4200 Standard specifically states that a "pneumatic backup (PB) system shall be required on each car to apply emergency brake cylinder pressure in the event of a vented brake pipe." *See* FRA-2006-26175-7 at p. 8. Establishing different brake pipe leakage limits, or eliminating them altogether, for all — or even the non-dual mode subset of — ECP equipment is a prescription for confusion and unnecessary risk.

FRA also seeks comments on whether and how the nominal piston travel adjustment limit should be flexible. 72 FR 50836. We believe that the language proposed for Section 232.607(f) adequately addresses this subject. However, we stress, again, the need for FRA to approve Subpart G training programs to ensure that the necessary crafts are appropriately instructed on this difference from how conventional pneumatic brake piston travels are set and communicated.

### **Proposed Section 232.609**

Continuing on to Section 232.609, we are strongly opposed to the proposal in subsection (a) that would permit a train operating in ECP brake mode to depart from its initial terminal with ninety-five percent effective and operative brakes under certain circumstances. In support of this proposal, FRA claims that "ECP brake system technology provides the ability to continuously monitor the real-time status of the braking system on each car in a train," which "allows a locomotive engineer to always know the *exact status* of his train's braking system." 72 FR 50837 (emphasis added).

As I said before, Section 3.5.4.2 of AAR Standard S-4260, states that "CCDs with a low or missing battery are counted as inoperable, *but may not be displayed as inoperable* until the total inoperable reaches less than ... 85% with trainline power ON." *See* FRA-2006-26175-13 at p. 36 (emphasis added). Thus, a HEU display of 95% operable brakes may not reflect all the brakes in the train that are inoperable, meaning that the locomotive engineer *does not* always know the exact status of the braking system.

If, as FRA states, the percentage of cars that are discovered to be defective for the first time while the railroad is conducting pre-departure inspection and testing is "very small" (72 FR 50837), any resultant delays in ensuring 100% operability will be *de minimis*. As we stated during the first public hearing, this is an issue of mere operational convenience for the industry, and we again strongly urge FRA to reconsider this aspect of its proposal, and we urge reconsideration of proposed Section 242.609(e) for this reason, as well.

We also oppose proposed Section 232.609(b) for the same reason. What distinguishes an ECP-equipped car from a conventional, pneumatically-braked car are (1) the control valve, and (2) the wiring, piping, and associated couplers for transmission of data between the CCD and the HEU. We find it incomprehensible that the industry would implement state-of-the-art ECP technology on any scale and then fail to stock replacement parts and/or train a sufficiently-sized inspection and repair force, except at 3,500-mile intervals. However, Subsection (b) appears to invite the industry to do just that.

It appears to us that proposed Section 232.609(d)(4) prohibits a railroad from opting to move an ECP-equipped train with less than 85% operative brakes in “Switch” mode to the nearest rearward location where necessary repairs or changes to the consist can be made. We can conceive of a number of situations where the location to the rear is significantly closer than the nearest forward location and such a movement is less disruptive than continued forward movement. If FRA has intended to prohibit a “backhaul,” we are interested in the rationale. If, however, no such prohibition is intended, we suggest that FRA clarify this provision.

We also note that FRA devoted a significant portion of its section-by-section analysis of Section 232.609(d) to the importance of the visual inspection required when a train’s operative brakes fall below the 85% threshold. *See* 72 FR 50838–50839. The training provided those who will perform these inspections — including operating crews — is the foundation that will provide continued safe movement. For this reason, we again urge FRA to require that all Subpart G training programs be submitted for approval.

With regard to proposed Section 232.609(i), FRA seeks comment on several specific issues: (1) with respect to electronic tagging of defective ECP brake equipment, rules concerning display or monitor placement or the merging of various data into a smaller number of displays may be appropriate to minimize or eliminate the potential that locomotive engineers may be distracted or subjected to information overload by multiple monitors or displays in the locomotive cab, thus potentially endangering the safe operation of the train; (2) how secure an electronic tagging system must be; (3) accessibility of the information, and whether the proposed rules should include provisions allowing for the manual input of non-ECP brake defects into ECP brake systems for electronic tagging purposes; and (4) what requirements and allowances should be made in consideration of that interest, including means to associate or merge ECP brake system information with information not monitored electronically by the ECP brake system. *See* 72 FR 50840.

Concerning the question of monitor overload we have a couple of factors that FRA should consider as this rulemaking moves forward. One is that, as PTC technology is implemented on routes where ECP braking systems are in use — and vice versa — Part 236 will be implicated. Appendix E to Part 236 addresses human-machine interface design, and we believe should apply in ECP/PTC territory. The other is that the Booz | Allen | Hamilton project on the locomotive “moving map” display is moving forward. We do not believe that this issue may be ripe for resolution in the Final Rule if it is promulgated in the coming months. However, we urge FRA to note in the Preamble to the Final Rule that this issue is being studied further and is likely to be addressed in some detail in a future rulemaking.

As to the issues of electronic tagging system security, access to information and merging of ECP-related and non-ECP-related information, we believe the solution lies in identifying the best practices from current electronic recordkeeping systems. All major freight railroads maintain electronic recordkeeping systems for 92-day locomotive inspections and — to the best of our knowledge — they have been proven to be secure. Similarly, some railroads have moved to electronic recordkeeping for Hours of Service that includes reporting of locomotive defects. We have identified problems with at least one of those systems that I will not detail further because it is beyond the scope of this proceeding. However, I do believe that resolution of these issues should take into account the efforts of the RSAC Locomotive Safety Standards Working Group pertaining to electronic recordkeeping.

Proposed Section 232.609(j) addresses procedures for handling ECP brake system repairs and designation of repair locations. As to the requirement in Subsection (j)(1) that railroads adopt and comply with specific procedures relative to the movement of defective equipment, we urge FRA to require that such procedures be filed with FRA, rather than merely being made available to FRA. We support the designation and notification requirements set forth in Subsection (j)(2).

We do not support proposed Section 232.609(k), nor do we believe FRA should invoke its discretionary authority under 49 USC Section 20306 to except certain operations involving freight cars and trains equipped with ECP brake systems from the statutory movement-for-repair provision. Our opposition is based on the same reasons previously stated in my review of Sections 232.609(a) and 232.609(e), which I will not belabor here. Furthermore, there is one passage in the Preamble concerning this section that requires clarification by FRA. Specifically, in the section-by-section analysis of Section 232.609, FRA stated as follows:

Paragraph (a) implicitly excepts trains operating in ECP brake mode from § 232.103(d). Paragraph (k) intends to clearly and explicitly except § 232.103(d). *An explicit exception in this rule does not imply that there are no independent and implicit exceptions.*

72 FR 50841 (emphasis added). We understand what FRA means with respect to paragraphs (a) and (k). However, we are compelled to ask what other “independent and implicit” exceptions are contained in the Proposed Rule that have not been identified in the Preamble.

### **Proposed Section 232.611**

Turning, now, to proposed Section 232.611, we have several comments. During the first public hearing, an industry spokesman termed the impedance testing required by proposed paragraph (a)(3) as “of no value.” We strongly disagree. Attached to my written testimony as Exhibit BLET-1 is a reprint of an article from *Medical Device & Diagnostic Industry* magazine on this subject. Of particular relevance to this proceeding is the following excerpt:

Unlike many types of electronic products, medical equipment such as defibrillators and pacemakers must meet unusually high standards for performance; their failure can cause injury or death. Pacemakers typically remain dormant for extended periods, waiting for a

signal, so failure is often not detected until too late for a routine response. Defibrillators must deliver high-voltage pulses on demand, often in harsh environments.

The article goes on to establish the need for impedance testing and demonstrates the ease with which such testing may be performed. ECP brake failure can have the same dire consequences as the failure of critical medical equipment. Similar to a pacemaker, ECP can remain dormant for extended periods, waiting for a signal. Like a defibrillator, ECP often operates in harsh environments. FRA should reject the industry's opposition to the impedance testing requirement and retain it in the Final Rule.

Proposed Section 232.611(b) addresses standards for single car air brake — or SCAB — tests. In the section-by-section analysis of this subsection, FRA noted that “AAR and ECP brake manufacturers are currently in the process of developing [SCAB] test procedures for ECP brake equipped freight cars,” and that “[s]hould such procedures be formalized in an AAR approved and published standard prior to issuance of a final rule in this proceeding, FRA will consider incorporating that standard into the final rule.” 72 FR 50842. In the event such a standard becomes available prior to issuance of the Final Rule, we would urge FRA to publish the standard in this docket and reopen the comment period.

In Section 232.611(c), FRA proposes to require that SCAB tests be performed upon the occurrence of any of the events identified in Section 232.305, except for paragraph (b)(2), which requires railroads to perform a single car air brake test when a car is on a shop or repair track for any reason and has not received a single car air brake test within the previous 12-month period. FRA's rationale is that, because of “the ECP brake system's ability to continuously monitor the condition of a car's air brakes, FRA believes that less frequent single car air brake tests are justified on such equipment.” *Id.* We disagree, for the reason noted in the Final Report of the Failure Modes, Effects, and Criticality Analysis of the AAR S-4200 Standards with respect to an ECP-equipped car's pneumatic back-up:

We recommend continuation of periodic single car testing to assure PB [(Power Brake)] Functionality ... PB functionality should be verified on last car of train wherever possible.

FRA-2006-26175-4 at p. 16. For the same reason, we oppose Section 232.611(f).

### **Proposed Section 232.613**

Finally, with respect to proposed Section 232.613, we support FRA's general approach, as well as its rationale for establishing separate standards applicable to ECP EOT devices in lieu of Subpart E. *See* 72 FR 50843. However, there is one area where we seek additional clarification. FRA states that an ECP EOT device does not need to perform the function of venting the brake pipe to atmosphere to engage an emergency brake application because it will respond to an emergency brake application command electronically transmitted by the HEU, which is true in normal circumstances.

Subpart E requires that a two-way EOT must be designed so that an “emergency brake application command from the front unit of the device shall activate the emergency air valve at

the rear of the train within one second.” 49 CFR § 232.405(a). FRA’s rationale is correct for a stand-alone ECP system and for dual mode ECP systems that are operating in ECP mode and there is no electrical malfunction. However, we can envision two scenarios in which an ECP EOT device could be called upon to perform the function of venting the brake pipe to atmosphere to initiate an emergency brake application from the rear, assuming the train — if conventionally braked — would be required to be equipped with a two-way EOT pursuant to Section 232.407.

One is a dual mode ECP train operating in conventional mode, whether from the initial terminal, or after having departed the initial terminal because of some failure of the ECP system. The other is any ECP train operating in ECP mode where the locomotive engineer is forced to initiate a traditional pneumatic emergency application, utilizing each car’s pneumatic back-up, because the ECP system is not responding to the engineer’s train brake command. In either of these circumstances, none of the ECP “advantages” are available, nor would the engineer be able to also initiate a pneumatic emergency application from the rear. It appears to us that the Proposed Rule fails to anticipate and properly safeguard against either of these “worse case scenarios.” We urge FRA to revisit Section 232.613 to ensure that there hasn’t been an inadvertent omission.

### **FRA’s Regulatory Analysis**

I also would like to respond, briefly, to FRA’s Regulatory Analysis, which is docketed as Document #16. We believe the assumptions upon which FRA based its analysis generally are sound and realistic. *See* FRA-2006-26175-16 at pp. 7-8. We appreciate FRA requesting comments and information concerning the following subjects, and ask that FRA hold the comment period open until such time as the projections have been provided and we have had an opportunity to review and comment on them:

- how often under the proposed rules that railroads expect cars will be off air for more than 4 hours, but less than 24 hours (id. at p. 21);
- how often trains currently require reassembly at their initial terminals to ensure 100% effective and operative brakes or cut-outs en route to ensure 85% effective and operative brakes (id. at p. 22);
- ECP end-of-train device savings (id. at p. 23);
- velocity improvements on mainline corridors (id. at p. 24);
- environmental cleanup cost estimate for accidents (id. at p. 41);
- cost per set-out (id. at p. 44);
- the value of track out-of-service time for ECP trains (id. at p. 48); and
- the maintenance of ECP brake systems for locomotives (id. at p. 53).

We are not in a position to address with specificity the magnitude of the cost decline that would flow from large-scale implementation of ECP technology. That said, we concur with FRA's expectation that conversion costs will decline over time due to economies of scale and experience. Id. at p. 51.

However, we do believe FRA's projection for training costs are unrealistically high. The "average wages per employee hour" of \$25.68 appear — to us — to be reasonable if the figure includes the actual hourly rate paid, plus the railroad's Railroad Retirement and Medicare tax liability. Id. at p. 54. But we disagree that the rate should be further loaded to reflect any overhead costs, such as fringe benefits. Training will be provided as part of, or in lieu of, work time, and there is no indication that any railroad will have to engage in any hiring in order to meet its training requirements. Furthermore, we believe the length of training that actually will be provided to train crews will be significantly less than the "24 hours of initial training and 8 hours of annual training" projected by FRA. Triennial Part 240 recertification processes seldom take more than 24 total hours on many railroads, and the industry has fallen into the habit of "shoe-horning" added recurrent training into existing one-day programs. Therefore, we believe this element is overstated.

We agree with FRA that this proposed rule would not have a significant economic impact on a substantial number of small entities. Id. at p. 61. The Proposed Rule does not require any entity to implement ECP technology. Rather, it permits each entity to make its own decision based upon a cost/benefit analysis unique to that entity. The same is true with respect to FRA's assessment "that this proposed rule would not have an economic impact on any small entities." Id. at pp. 64-65.

### **AAR Standards to Be Incorporated**

Before concluding my testimony, I would like to place in the record a number of other issues that arose during our review of the docket in this matter. While they are, by and large, subjects that also are relevant to the Technical Conference that will follow this hearing, they are of sufficient concern that FRA should take note of them in this proceeding.

The first is the fact that most, if not all, of the AAR standards FRA proposes to reference by incorporation, themselves, reference other AAR standards. In almost every case, the reference is to the "latest revision" of the standard being referenced. The proposed rule incorporates only specific editions or revisions of each of the AAR standards, and AAR must comply with a process by which a revised standard can be substituted for an incorporated standard in a FRA regulation. We believe clarification — either in the AAR standards or in the Preamble of the Final Rule — is necessary to prevent confusion or misapplication of a revised standard that has not been incorporated into the rule by FRA.

With respect to AAR's S-4200 Standard, we have the following concerns:

- Section 4.2.2.2.4 states: "For trains with cars that do not have local load sensing capability, the engineer must designate if the train is empty or loaded prior to moving the train." At some point during ECP implementation, trains comprised of mixed

loads and empties will be operated with ECP technology; how will the standard and/or FRA's regulation address this eventuality?

- Section 4.2.2.2.5, captioned “Train Net Braking Ratio,” states: “The requirements for a specific train net braking ratio during ECP braking shall be railroad specific in that not all railroads may want the ability for the engineer to make changes. If the optional ability to change the train NBR is provided, then the engineer may select the desired train NBR, or the engineer may accept the railroad’s default setting.” Given the reality that locomotive engineers in many portions of the industry operate on more than one railroad, how will the potential for different NBRs during a single trip be handled?
- Section 4.2.3 states: “If the [ECP] initialization procedure is cancelled, the HEU returns to the setup process and/or allows the engineer to restart the initialization process.” Is there a limit on the number of automatic or manual restarts before system is deemed to have failed and, if so, what is that limit?
- Section 4.2.3.1.1, setting forth general sequencing requirements, states all of the following: “When sequencing is completed successfully, each vehicle shall retain its position and orientation. ... Successful sequencing shall not be required for normal train operation. ... Any failures related specifically to sequencing shall not affect normal train operation.” Under what operational circumstances is sequencing required, and what will be the responsibility of the crew with respect to sequencing?
- Section 4.2.5.3.1 classifies general faults. Will crews be trained on recognizing and dealing with all three classes of faults and, if not, which faults will not be included in the training?
- Section 4.3.1.3 is entitled “Engineer Controls.” Subsection 4.3.1.3.2 states that “[m]eans of implementation of other required inputs shall be manufacturer specific.” What steps will be taken to avoid distracting engineers and not providing them with consistent information in a consistent manner?
- Section 4.3.14.1 states that the “battery backup system within a CCD may be configured to allow the device to operate normally from train line power with a fully discharged, failed, or missing battery. A CCD in this condition may be considered as operative for the calculation of percentage operable brakes until the combined total of CCDs in this condition and other inoperative CCDs exceeds the penalty brake threshold.” We are concerned with the possibility that a train with multiple CCDs experiencing battery problems suddenly going into failure mode with no indication to the crew of a looming problem.
- Section 4.4.14, entitled “CCD Detects Train Empty/Load Command Mismatch,” states: “If a CCD detects a train empty/load command mismatch, it shall report an invalid empty/load command status to the HEU when polled. CCDs that are responding to the train empty/load command shall default to a LOADED state when a

command mismatch is detected.” We have two questions concerning mismatches: First, what is the difference in braking performance between the empty status and the loaded status? And, second, when the system automatically defaults to the “loaded” state, what warning, if any, will the crew be given?

- Section 4.4.15 notes that high priority exception messages (e.g., hot bearing detected, wheels on the ground, severe truck hunting, severe harmonic rocking, stuck hand brake, etc.) shall be displayed to the engineer. However, others — such as CCD system self-diagnostic test failures, trailing HEU not sending status messages, and car sensor detection of worn brake shoes — will appear only on diagnostic screens and be saved in an event recorder. Why aren’t worn brake shoes considered a high priority exception message in a system that is touted as providing “the ability to continuously monitor the real-time status of the braking system on each car in a train” that allows a locomotive engineer “to always know the *exact status*” of his train’s braking system? 72 FR 50837 (emphasis added).
- Section 6.3.6.3.1 states that cars with test freight brake control valves will be stenciled: “CONDITIONALLY APPROVED CCD; IF DEFECTIVE, CALL CAR OWNER,” and Subsection 6.3.6.3.1.1 requires that car owners of test valves must keep accurate records of any malfunctions of CCDs and report such information to the AAR Office of Safety and Operations. How long will AAR retain such reports, and to whom will they be accessible?

Concerning AAR’s S-4250 Standard we have the following issue:

- Section 4.11.3.2.2 states: “If multiple remote exceptions are active on a remote locomotive, the highest priority event exception shall be the first event sent to the ITC lead. One second after the transmission of the highest priority exception message, additional exception messages for events of equal or lower priority may be sent at manufacturer’s discretion. If sent, these subsequent exception messages shall be transmitted in order of priority at a rate of no more than one exception message per second.” Given that the engineer will not have his or her eyes glued to the display at all times, will multiple exceptions keep cycling on the display until cleared?

And, finally, concerning AAR’s S-4260 Standard we have the following questions:

- Section 3.4.4 is titled “CUT-OUT of an Overlay CCD without Stuck Brake Protection” and states: “This section will be used as a placeholder and if this test is required as part of the inter-operability test procedure, it will be added here.” If the test is added at some point, how will the ensuing revision be handled in terms of FRA incorporation of the standard in the rule?
- Section 3.5.4.2, entitled “Reduced Percentage of Operative Brake-CCDs with Low Battery,” states, in part: “The purpose of this test is to verify that the HEU correctly determines and responds correctly to a reduced percent operable when CCDs have a low battery. This test shows that CCDs with a low or missing battery are *counted* as

inoperable, but may not be *displayed* as inoperable until the total inoperable reaches less than 90% with trainline power OFF, or less than 85% with trainline power ON, at which time a penalty brake application will be commanded.” In view of my previously stated concern about the possibility that a train with multiple CCDs experiencing battery problems suddenly going into failure mode with no indication of a looming problem, is there any other warning — short of the car being reflected as inoperable on the display — that can be provided the crew of a train experiencing battery problems?

I thank you for your patience and will try to answer any questions you may have.

Exhibit BLET-1



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Originally published December 1996

## RELIABILITY

### Innovations in Impedance Testing

Jim Richards

Unlike many types of electronic products, medical equipment such as defibrillators and pacemakers must meet unusually high standards for performance; their failure can cause injury or death. Pacemakers typically remain dormant for extended periods, waiting for a signal, so failure is often not detected until too late for a routine response. Defibrillators must deliver high-voltage pulses on demand, often in harsh environments. Hearing aids, while not crucial for maintaining life, must also function reliably, and their extremely dense construction and diminutive size require that component tolerances be tighter than those of many other products.

A key factor in the safety of these devices is impedance, the opposition to ac current flow offered by a device or circuit. A complex value made up of resistance, inductance, and capacitance, impedance can help determine whether a device or circuit will function to specifications. Unfortunately, its role in device reliability is often overlooked; in fact, industry standards do not even specify necessary impedance values. Yet impedance should not be ignored as a safety factor.

With their special safety requirements, medical electronics can benefit substantially from impedance measurement.

Many medical equipment manufacturers routinely perform impedance tests on their components at one or more stages in production, as early as incoming inspection and as late as final testing (see Table I). However, it is likely that just as many manufacturers rarely if ever perform these tests.

One reason for this is undoubtedly that many design engineers think impedance measurements are difficult to conduct and require a toolroom full of instruments and a tangle of cables, banana plugs, and baby Neill Concelman connectors. While that was certainly true a decade ago, today, thanks largely to advances in digital signal processing and semiconductor technology, there are instruments available that make impedance measurement clean and simple. They can display the resistance, inductance, and capacitance parameters of an impedance measurement as well as calculate and display many other related parameters, such as impedance, yielding admittance, reactance, conductance, susceptance, and dissipation.

## INSTRUMENT ADVANCES

In the past, the instruments used to perform impedance tests were either meter types, which measured voltage or current and left it to the operator to calibrate the impedance quantities, or bridge (null) types, which required an adjustment and indicated impedance on a scale or dial associated with a variable component of some kind. Meters were faster and easier to use, but bridges were more accurate.

Today's instruments have the best characteristics of both types of instruments, with few of their eccentricities. Digital in design, these new machines provide the typical array of features of this type of equipment, such as Institute of Electrical and Electronics Engineers (IEEE) bus control, nonvolatile memory for instrument setups, broad configurability, ease of use, and the ability to be upgraded in place.

Because impedance measurement requires rapid and accurate ratio calculations, microcomputers are well suited for this testing and are the basic component of all modern impedance equipment. While these new instruments perform the functions of a bridge, they lack a null function, instead successively measuring the voltage across the unknown resistor and the voltage across a standard resistor carrying the same current, and then dividing the results.

Four helpful features available in today's instruments include swept parameter measurement capability, menu programming, test data collection, and setup storage. Swept parameter measurement provides values over a user-specified frequency range and delivers the information in graphical or tabular format via the display or printer. Menu programming allows operators to access test conditions with the touch of a button. Test data collection allows test results to be stored automatically on an internal diskette drive or transferred to a PC for further analysis. Setup storage allows operators to store commonly used test routines.

## TIPS ON HANDLING AND MEASUREMENT

Thanks to these new instruments, making impedance measurements today is relatively simple. However, care must still be exercised to ensure reliable results.

Especially important for surface-mount manufacturing is the need for careful handling of small parts. The size of these devices often makes it difficult to obtain good electrical contact. One of the most useful tools is the Kelvin clip cable, which allows four-terminal connections to be made to passive components. It is especially useful for testing low impedances encountered with components such as electrolytic capacitors and inductors.

A set of chip component tweezers that plug directly into the instrument is also helpful. The tweezers allow the devices to be picked up, measured, and placed in the proper bin in one operation.

The same results can be obtained with a component test fixture. Chip component fixtures ensure that tiny devices are nestled securely so measurements can be made easily and quickly. The same level of electrical contact obtained with Kelvin clip cables can be obtained with a test fixture.

Remote high-voltage test fixtures are necessary when high voltages are required to make the measurement. A safety interlock allows the person making the measurement to place a component in a fixture, make the measurement, and remove the component without risk.

#### CHOOSING THE NUMBER OF CONNECTIONS

Impedance measurements can be made using 2, 3, 4, or 5 terminals. Two-terminal measurements are easiest and typically are used in the impedance range of  $100\Omega$  to  $10\text{ k}\Omega$ . Three-terminal measurements (made with two terminals and a guard) are useful for high-impedance measurements when the effects of stray capacitance can introduce errors as well as when guarded, in-circuit measurements are necessary.

Four-terminal measurements (with two current and two potential terminals) are required to obtain accurate impedance measurements below  $100\Omega$ . The method eliminates series impedances and contact-resistance errors. Five-terminal measurements are made when results over a wide impedance range are desired.

When low impedances are measured, a two-terminal connection introduces errors caused by the addition of the series impedance of the connecting leads. As a result, instruments now use the four-terminal method to perform low-impedance measurements.

The terminals carrying the current are called the current terminals and those used to make the voltage measurement are called the potential terminals. The proper method for a given application is determined by the measured impedance value and the accuracy required.

#### OTHER TEST CONSIDERATIONS

The basic measurement parameters such as voltage, frequency, and equivalent circuit are determined by national and international standards and manufacturer specifications. Generally, low impedances such as large-value capacitors and low-value resistors and inductors are measured using a lower frequency, such as 100 Hz or 1 kHz, in the series configuration. For small inductance, higher measurement frequencies are required.

Because many instruments allow the user to select measurement speed, it is tempting to attempt the measurement in the shortest possible time. However, the higher the measurement speed, the lower the accuracy. Instruments that offer autoranging will automatically find the proper range for a given measurement, but locating the proper range can add time to the measurement.

#### CONCLUSION

Medical devices such as defibrillators and pacemakers must perform unfailingly, often without periodic testing. Thus, manufacturers must perform an exhaustive battery of tests as they are developing and producing these types of devices. Incorporating impedance measurements in these test routines is an important part of ensuring a high level of performance, and thanks to advances in measurement equipment, the impedance tests can now be performed easily.

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