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VOLUME 5 — PERFORMANCE EVALUATION TESTS

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16. Abstract

This document reports on a preliminary evaluation of the Human Factors design proposed for a line haul freight locomotive cab. The program was conducted using a full scale hard mock-up of the proposed design and the evaluation was provided by engineers from the former Penn Central Transportation Company. During the program the techniques utilized were evolved to evoke the maximum response and cooperation from the various subjects. In general the concept was favorably received.

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PREFACE

The Department of Transportation is sponsoring a research program to develop a locomotive cab design under the technical direction of the Transportation System Center for the Federal Railroad Administration. As part of the design development program a full scale hard mockup of a cab design was constructed. The mockup was used as a human factors tool to assess the new design concept. Experienced locomotive engineers from the former Penn Central Transportation Co., participated in the evaluation and testing of the mockup. This document presents the results of the evaluation and test program.

The author would like to thank the Penn Central for arranging for the contact with the engineers, particularly Mr. Joseph Spreng Assistant General Manager. The author would also like to acknowledge the contribution of Dr. John Jankovich, the Technical Monitor, for his comments on the test plan; Dr. Donald Devoe, who witnessed one of the test sessions; Mr. Norman Macdonald of the Electro-Motive Division of General Motors, the principal subcontractor; who was a member of the test team; and Mr. William McLean, Boeing Vertol R&D Manager, who provided the necessary program and administrative direction.

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1. INTRODUCTION

DOT/TSC is funding a program to design and develop a modern cab for line haul freight locomotives. As part of this program a full scale mockup of a locomotive cab was built. The cab mockup was used in a preliminary test program to demonstrate its utility in a modern freight environment. The test program is considered a logical extension in the design development process. It provided an opportunity to perform a design iteration based on an analysis of engineer performance and preference. This was important because if design deficiencies were found to exist or additional concepts were identified that needed testing, modifications to the cab design could easily be incorporated and evaluated prior to committing to a more extensive program such as prototype hardware.

The second purpose of the test program was to gain experience applying the techniques of human factors evaluation to locomotive cabs. The test procedures were reviewed to improve them in the event further testing is contemplated in the mockup and to refine a research tool that could be applied in a research or operational setting.

The locomotive cab mockup performance evaluation tests were conducted during the period April 12 to April 28, 1976. The test personnel included eleven engineers from Conrail (formerly Penn Central) and one officer of the Brotherhood of Locomotive Engineers (BLE).

As expected the participants exhibited many individual preferences based on their experiences in train handling and the idiosyncracies of their operating division. However, the overall design concept was very favorably received by all the men.

The procedures used and the test results are described and discussed in the following sections.

2. TEST PLAN

2.1 TEST SITE

Prior to conducting the performance tests, a test plan was prepared. This test plan is included in this report for reference as Appendix A. It is appropriate however, to discuss it briefly.

The mockup evaluation was conducted at the Boeing Vertol factory. The mockup was mounted on a wooden platform ten feet wide, twenty feet long and five feet high to locate the cab at its proper operational height above the rails. A photograph of the mockup mounted on the platform is shown in Figure 1.*

The platform was placed over a section of track as shown in Figure 2, to provide some visual realism.

2.2 PERSONNEL

The test participants were from the Northeast Corridor of the Consolidated Railway Corporation (Conrail). There were twelve experienced enginemen including one officer from the Brotherhood of Locomotive Engineers (BLE). The men were selected from a list of enginemen who had expressed interest in improving the design of locomotive cabs. The list was provided by Mr. Joseph Spreng Jr., Assistant General Manager, Central Region of Conrail.

The men were all highly qualified and were presently operating or supervising trains in high speed service on the Northeast Corridor. They represented a cross section of experience from the New Haven Line, Harrisburg District, Washington, New York and Philadelphia.

The men weighed from 155 to 255 pounds, their heights varied from 68 to 75 inches and their ages ranged from 32 to 60 years. Their years experience varied from 3 to 25 years. All of the men were experienced in both line haul freight and passenger service. Four of the men had experience on the mountainous terrain near Harrisburg and two were familiar with early versions of radio controlled, locomotive helper devices. They had handled trains in a variety of cabs on both electric and diesel/electric locomotives. Some examples are GG-1, E-44, Metroliner, SD35, and U38. One man had operated a turbo train while another had steam experience. Each man spent an entire day at the test site.

During the course of the program the evaluation and tests were witnessed on one day by Dr. Donald Devoe of TSC, Mr. Harry Eck, Supervisor of Locomotive Operations and Mr. Larry Kast, Manager Locomotive Training Center of the Chessie System.

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*The details of the mockup are described in LOCOMOTIVE CAB DESIGN DEVELOPMENT, Report No. D339-10043-1, Volume 3 - Design Applications Analysis.

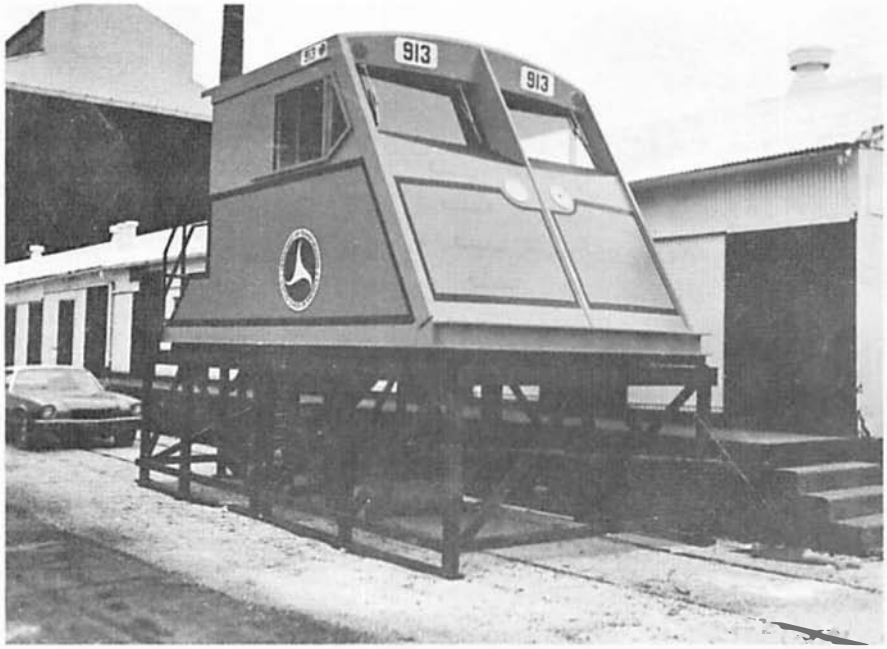

Figure 1. Mockup Exterior View

Figure 2. Visual Realism

3. TEST METHOD

The assessment of the locomotive cab mockup was done in the following sequence.

1. Pretest briefing
2. Evaluation and test
3. Post test debriefing.

3.1 PRETEST BRIEFING

Each participant was supplied with a copy of the operator's manual (Locomotive Cab Design Development, Volume 4, Report No. D339-10026-1) prior to his scheduled appearance at the test site. All stated that they had read it and many had marked up the margins with questions.

The pretest briefing was conducted in three phases.

1. Introduction
2. Familiarization with mockup concepts
3. Test instructions.

3.1.1 Introduction

Upon arrival at the test site, approximately one half hour was spent in explaining the purpose of the project and getting the engineer relaxed. To provide an appropriate frame of reference, it was explained that the Locomotive Cab Design Development Program is being conducted as part of a research effort to evaluate new concepts in cab control/display design, operating procedures and general working and living environment.

It was further explained that the engineers proficiency was not being tested but rather that it was their collective experience in existing cabs that provided the necessary expertise to further develop the design concept along utilitarian lines. They were encouraged to consider that someday they or their associates may have to operate a locomotive derived from the present design and therefore to be candid during their critique. Thus, every effort was made to set up an atmosphere in which the men would feel they could be as critical and subjective as possible and that the test personnel were not looking for compliments nor would their feelings be hurt.

This aspect of the briefing was a valuable feature of the test program. In fact several of the engineers later said that they had experienced some apprehension as to what would be expected of them when they arrived at the test site. This suggests that if further tests are done the engineers be sent a schedule and a statement of what is required of them so that they know what to expect.

3.1.2 Familiarization with Mockup Concepts

The second part of the prebriefing consisted of an introduction to the new design concept. Briefing materials included photographs, sketches and the operator's manual. The engineers attention was directed to the similarities and differences between the new design and cabs he was accustomed to.

The engineer was shown the slides in serial fashion; that is, starting with an overview of the mockup exterior and crew station and ending with detailed drawings of the various controls and displays. After the presentation of the general cab features, the engineer was shown photographs of the Electro-Motive Division (EMD) of General Motors "Clean Cab" mockup built at the request of the Locomotive Control Compartment Committee. (The work of this committee is discussed in Locomotive Cab Design Development, Volume 3, Design Application Analysis, Report No. D339-10043-1.) He was told that safety features developed under the "Clean Cab" program would be incorporated in the new cab design if appropriate. During the course of this informal briefing the man was asked his opinion on a variety of topics and was encouraged to ask questions.

This dialogue was established because all of the men had strong and divergent views on at least some of the mockup features.

3.1.3 Test Procedures

The third part of the prebriefing concerned the test procedures. The engineer was instructed that he would be given the opportunity to inspect the mockup in every detail. He was told that he would be required to perform simulated locomotive and train handling procedures contained in the operator's manual according to a prepared scenario. Upon completion of the mockup inspection and checkout of procedures he would be required to rate each mockup item. The ratings would be done in the mockup to provide the engineers with the opportunity for a more detailed inspection of a feature prior to assigning a rating.

3.2 MOCKUP EVALUATION

Following the briefing the engineer was taken to the cab mockup and walked around the outside. A brief description of the crashworthiness concept followed. The men were generally pleased with the crashworthy concept. When asked whether they missed a nose door they said "No", and appreciated the lack of drafts and leaks which accompany any forward opening. When asked if they missed the protection of the short hood they said "No", since they were accustomed to Metroliners and other MU equipment which affords little protection. They noted that the slanting windows offered better deflection possibilities against flying objects. Most of the men, when asked, wanted the switchman's step on the right front corner, although a few wanted it located under the side cab window. They also liked the high cab conspicuity.

The engineer was then taken into the mockup and spent some time familiarizing himself with the interior design (see Figure 3.) He reviewed the

Figure 3. Interior View – Looking Forward

lavatory compartment and noted its features. The men all liked the light colored cab interior, although one man did remark that the aluminum interior which is in some PC cabs had been too bright and glary. They did not feel that a brakeman's window was necessary on either side of the cab and did not mind the blind spots. Most of the men wanted the third seat behind the trainman's seat, a few wanted it in the middle and one wanted it back against the rear wall. They all liked the high operating position and liked the raised platform since it got them out of slush, water, and drifts. They all appreciated the work console surface with a place for train orders and timetables. It was noted that a lip around the console would be desirable to keep objects from rolling off. One man suggested a small shelf just under the left of the operator's console to store small items. All of the men wanted an adjustable rear view mirror that was vibration proof. Some of the men wanted a full length rear view mirror while others desired a glass wind vane with the mirror on the bottom. The consensus was that brow lighting under the top lip of the console was highly desirable and an additional utility light should be provided overhead at both work stations. This light should be controllable from both the work stations and by a switch located on the wall by the cab rear doors. The men liked the panel and instrument lighting. One man pointed out that it would be desirable to be able to change light bulbs without the use of tools especially phillips head screwdrivers. Recognizing that some states require that an ash tray be provided in the cab, the men suggested various locations in and around the control stand. Their major concern was that it should be in a place where ashes would not be blown up. The men suggested that the footrest be extended under the entire console, and that a similar footrest be installed at the trainman's console. Finally, several men stated that all items must be well maintained or the whole concept would be self defeating.

The engineer was then seated at the locomotive control console and allowed to work the controls and study the displays. A mission scenario had been prepared to provide the opportunity to use the new design features according to the procedures described in the operator's manual. Although the scenario was conducted in a static mockup, the engineer was able to get the feel of the location of displays and location of switches and controls. He was told that the locomotive was on the ready track with the engine shut down, and no air pressure. He set up his controls, simulated starting the engine, released the hand brakes, made a brake and sander test, set up lights, and prepared to move to the yard. When leaving the ready track, a cab signal and ATC test was performed. When on the main track, the engineer activated the reverse control panel to make a four-mile run backwards to the departure yard. He then coupled the locomotive to the waiting train, charged and tested the air brake system. The engineer then took the train out of the yard and picked up speed with his train. He power braked around a curve and used the train handling indicator as desired. After cresting a grade, he used dynamic braking down a hill. Regaining speed, he approached his destination and brought the train under control entering the yard. An emergency took place as the train negotiated a crossover. After recovering and entering the yard, he cut off his train, went to the diesel house and properly set up his controls before leaving the unit.

The scenario provided an opportunity for the engineer to exercise the cab features in a controlled sequence as he would when driving a standard production cab. The general comment concerning the controls and displays was that, "its different, but its handy and I would get used to it." These men were especially interested in and receptive to new ideas and innovative changes in part because of the wide variety of equipment which they operated.

Following the task simulation, the engineer was asked to rate cab items on a scale of 1 to 7, 1 being very inconvenient and 7 being most convenient to use. A 4 was considered the same as present locomotives. He was also asked to explain why he arrived at each rating. The ratings and the comments were entered on a prepared form (attached to the test plan in the appendix) and the test concluded.

3.3 POST TEST DEBRIEFING

Upon completion of the mockup ratings, the engineers were debriefed. This provided an opportunity to critique the design approach in its broader aspects, suggest improvements to the present design, identify areas where further investigation might be required and comment of the test procedures. Before they left, each engineer was told that if he had any additional suggestions or comments he should feel free to convey them to the test team. Several men said they would tell the brotherhood about the cab mockup at the first opportunity.

4. TEST RESULTS

This section presents the results of the mockup testing. First a summary of the ratings will be presented and then the ratings are discussed on an item by item basis.

Tables 1 through 12 show the engineers ratings of the various mockup features on the 7-point scale described previously. Next to the ratings two measures of central tendency are shown, the median and the modal ratings of an item and the range of the responses. These statistics were used to troubleshoot the data to locate potential mockup design problem areas. It should be noted, when examining these tables, that some items were not rated by all of the engineers. In most of these instances the engineers did not assign a rating because they felt they needed more experience with the item before a meaningful rating could be assigned.

Overall, 85 mockup items were rated plus an additional rating of the overall design concept. Ninety-two percent (78 items) of the items received a median score of six or greater. Eight percent (7 items) received a median score of less than six and were flagged as critical. These are denoted by an asterisk in the tables. Next, an item analysis was performed. All items rated below a 4 (comparable to present day production cabs) by at least one engineer were identified. The item was examined and comments summarized. These items are denoted in the tables by a double asterisk for each identification. The remaining comments were then reviewed and summarized. Following is a discussion of each item as it appears in the tables.

4.1 MAIN CONTROL PANEL

Figure 4 shows the arrangement of the main control panel. The following functions are contained on this panel and the individual ratings shown in Tables 1 through 4.

1. Sander control
2. Train brake control
3. Independent brake control
4. Throttle/dynamic brake control
5. Throttle/dynamic brake interlock
6. Stop all engines control
7. Direction control
8. Console lock
9. Emergency stop control
10. Bell control.

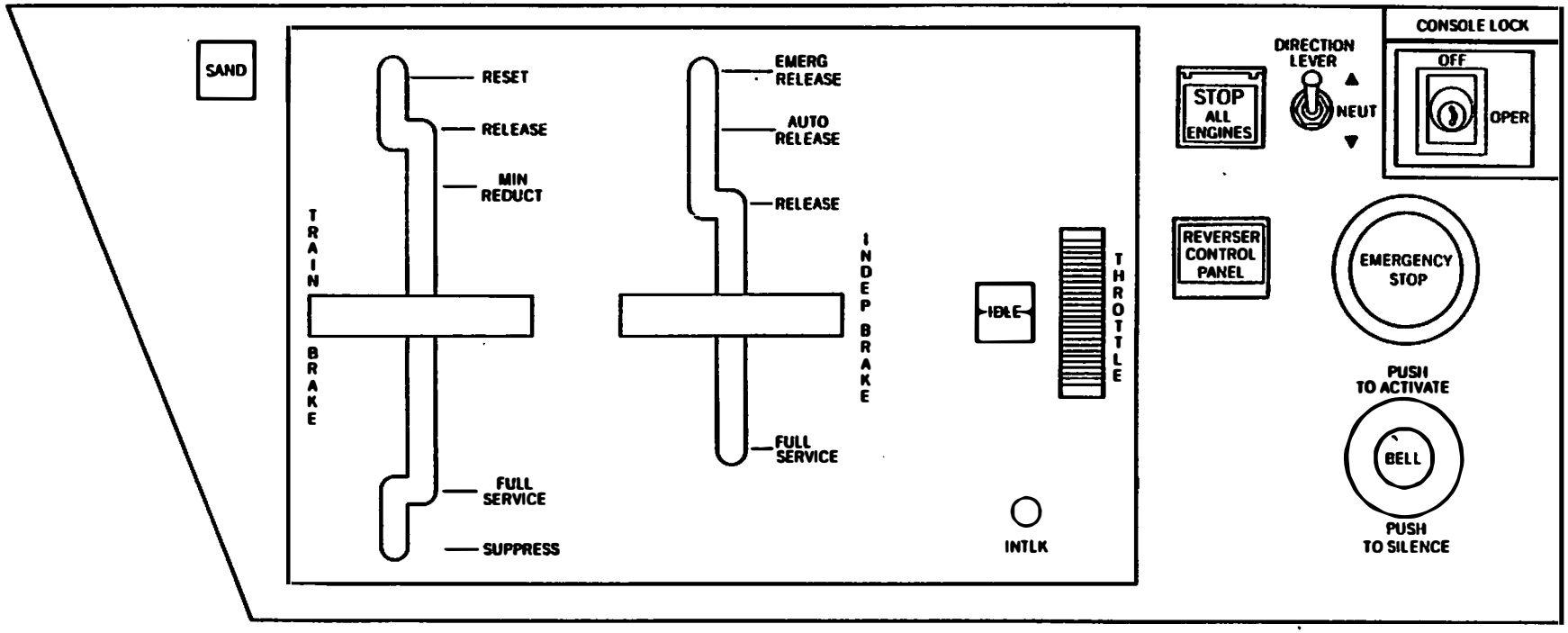

Figure 4. Main Control Panel

Table 1

The train brake lever handle location was generally acceptable, however, most of the men preferred the tee handle to be higher from the panel surface so that their fingers would more comfortably fit around it. One man noted that he could not see the release label when the handle was in the release position. One man suggested that the automatic brake have a straight back movement rather than gates so that it would be distinctly different from the locomotive brake. Most men wanted the train brake labeled "AUTOMATIC BRAKE". Finally, one man wanted the release position to line up with the release position of the independent brake for easy reference. With the exception of the suppression position, the remaining positions were deemed satisfactory. The 2 rating was assigned to the suppression position by the same man who down rated the train brake lever for the same reason, namely, that the gate is not necessary.

Table 2

The independent brake lever, with its auto release position was well received by most of the engineers. One man commented that he liked the auto release position because it frees his hand during high workload periods and would be an aid when power braking. One man felt that the emergency release position was not necessary, while another thought that the automatic release should be spring loaded.

Table 3

The throttle/dynamic brake controller was accepted by the majority of the men. Some suggested that the interlock be moved so that it could not be accidently engaged with the palm of the hand.

Some suggested that the window be made larger and provision made for providing dirt free or mar-proof material over the window. One man suggested a window on each side of the controller. Many of the men wanted the surface of the dynamic braking portion of the wheel, which is smooth, as rough as it is now in power and the power portion rougher than present. Officers of the Chessie System thought the wheel concept was ridicoulous for handling long heavy freight trains pulled by high horsepower locomotive consists but could not give a satisfactory reason why. Their position is questionable considering that high horsepower remote helper units are operated with table-radio size, rotary switches. The 1 rating was assigned by a man objecting to the reversed power setting from what he is accustomed to and another thought that dynamic braking and motoring should be controlled separately. The set up position should have a positive "snap-in" feel to it according to one man. Many of the men stated that the device did not have appropriate feel and one felt that the reverser control panel throttle would be more appropriate. One man stated that the wheel should have a pseudo click as the throttle/dynamic brake was advanced or retarded as an additional cue.

Table 1.

FEATURE

TRAIN BRAKE

ITEM	RATING 1	2	3	4	5	6	7	MEDIAN	MODE	RANGE
TRAIN BRAKE LEVER	-	1	-	3	3	3	2	5.2*	4,5,6	2-7
RESET POSITION	-	-	-	1	2	3	6	6.5	7	4-7
RELEASE POSITION	-	-	-	3	1	3	5	6.2	7	4-7
MINIMUM REDUCTION POSITION	-	-	-	2	1	5	3	6.0	6	4-7
SERVICE RANGE POSITION	-	-	-	2	2	3	5	6.2	7	4-7
FULL SERVICE POSITION	-	-	-	2	-	4	6	6.5	7	4-7
SUPPRESSION POSITION	-	1	-	2	-	4	5	6.2	7	2-7

Table 2.

FEATURE

INDEPENDENT BRAKE

ITEM	RATING 1	2	3	4	5	6	7	MEDIAN	MODE	RANGE
INDEPENDENT BRAKE LEVER	-	-	-	1	1	5	5	6.3	6,7	4-7
EMERGENCY RELEASE	-	-	1	-	2	3	6	6.5	7	3-7
AUTOMATIC RELEASE POSITION	1	-	-	-	1	2	8	6.8	7	1-7
RELEASE POSITION	-	-	-	1	1	3	7	6.6	7	4-7
FULL SERVICE POSITION	-	-	-	1	-	3	8	6.7	7	4-7

Table 3.

FEATURE

THROTTLE/DYNAMIC BRAKE

ITEM	RATING 1	2	3	4	5	6	7	MEDIAN	MODE	RANGE
THROTTLE DYNAMIC BRAKE HANDWHEEL**	1	2	-	5	-	2	2	4.1*	4	1-7
IDLE POSITION**	-	1	1	2	1	1	6	6.5	7	2-7
POWER SETTINGS	-	-	-	1	2	3	6	6.5	7	4-7
DYNAMIC BRAKE**	-	-	1	3	-	2	5	6.0	7	3-7
SET UP POSITION**	-	-	1	2	1	3	5	6.2	7	3-7
DYNAMIC BRAKE SETTINGS	-	-	-	3	-	3	4	6.2	7	4-7
INTERLOCK PUSHBUTTON	-	-	-	3	1	1	7	6.6	7	4-7

Table 4

Generally, the direction lever was favorably received. There were no objections to the lift to reposition feature, although some men wanted the positive lock feature in all three positions rather than just the neutral one. One man wanted the lever to have a higher (bat type) handle for a better grip. It should be recognized that the assumption underlying the use of this switch is that the engineer need only move the control in the direction that he desires to go without reference to the numbers 1 and 2 Ends of the locomotive. However, one incorrect setting, for example in yard duty, could have serious consequences in terms of the safety factors associated with locomotive movement. This possibility was examined during the test program and is discussed in the section concerning the reverse control panel. No one objected to the lighted arrows on the main control panel reverser switch.

None of the men objected to the relocation of the emergency stop pushbutton from the train brake controller to the right side of the control panel. However, one man did insist that the emergency stop should be a high resistance mushroom control and downgraded the present device accordingly. A second man said that he would prefer "EMERGENCY BRAKE" as the label for this device, rather than "EMERGENCY STOP".

The bell pushbutton (latching) location was acceptable to the men.

The men were told that the feed valve knobs were located in recessed compartments under the engineer's side window. This location was acceptable to all of them.

The manual sand pushbutton location was well received by the men. The majority of the men desired latching sanders although a few did not want the latching feature. The men did not seem to be familiar with the newer automatic sanding and wheel slip systems used on diesel locomotives today.

The reverse control panel pushbutton switch and the proposed position of the controls when making the changeover was acceptable.

The stop all engines pushbutton was well received by all the men and one man suggested that a placard be provided to remind the engineer that it is there. It should be noted at this point that no provision was made to evaluate deadman pedals. Some locomotives today have them and others do not. Our survey of trends for the next 10 to 15 years indicates that these devices will gradually disappear in their present form.

4.2 MAIN DISPLAY PANEL

Figure 5 shows the arrangement of the main display panel. The following functions are contained on this panel and the individual ratings shown in Table 5.

1. Brake pipe air flow

Table 4.

FEATURE

PRIMARY CONTROLS

ITEM	RATING 1	2	3	4	5	6	7	MEDIAN	MODE	RANGE
DIRECTION LEVER	-	-	1	3	2	1	5	5.5*	7	3-7
FORWARD POSITION	-	-	1	3	-	1	6	7.0	7	3-7
NEUTRAL POSITION	-	-	1	2	-	2	7	6.6	7	3-7
REVERSE POSITION	-	-	1	3	-	1	5	6.5	7	3-7
EMERGENCY STOP BUTTON**	1	-	-	1	-	2	8	6.7	7	1-7
BELL PUSHBUTTON	-	-	-	2	-	3	7	6.6	7	4-7
CONSOLE LOCK PUSHBUTTON**	1	-	-	-	1	1	9	6.8	7	1-7
FEED VALVE KNOBS	-	-	-	1	-	3	8	6.7	7	4-7
MANUAL SAND PUSHBUTTON	-	-	-	-	2	2	8	6.7	7	5-7
REVERSE CONTROL PANEL PUSHBUTTON SWITCH	-	-	-	1	-	2	9	6.8	7	4-7
STOP ALL ENGINES PUSHBUTTON	-	-	-	-	1	-	11	6.7	7	5-7

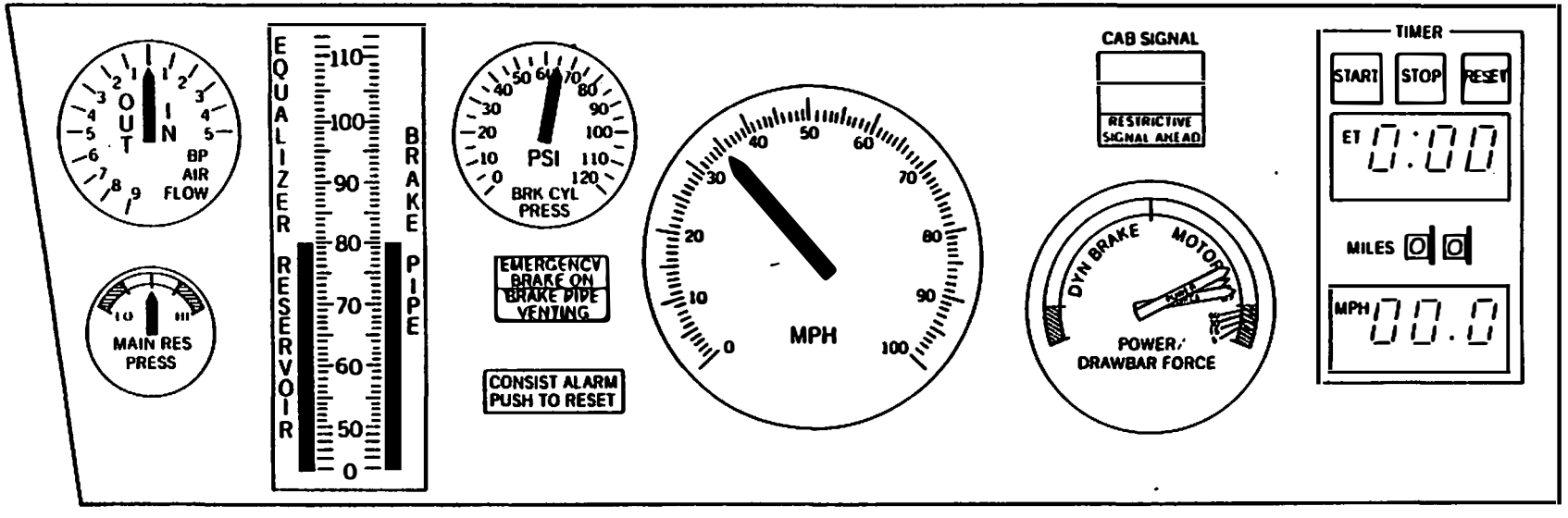

Figure 5. Main Display Panel

Table 5.

FEATURE

MAIN DISPLAY PANEL

ITEM	RATING							MEDIAN	MODE	RANGE
	1	2	3	4	5	6	7			
BRAKE PIPE AIR FLOW DIAL	-	-	-	1	1	1	9	6.8	7	4-7
MAIN RESERVOIR PRESSURE DIAL**	1	-	-	1	3	2	5	6.0	7	1-7
EQUALIZER RESERVOIR/BRAKE PIPE PRESSURE GAUGE	-	-	-	1	-	1	10	6.9	7	4-7
BRAKE CYLINDER PRESSURE DIAL	-	-	-	2	1	1	8	6.7	7	4-7
SPEEDOMETER DIAL	-	-	-	-	-	1	10	7.0	7	6-7
POWER/DRAWBAR FORCE DUAL POINTER DIAL	-	-	-	-	-	3	9	6.8	7	6-7
CAB SIGNALS**	5	1	1	1	-	1	3	2.5*	1	1-7
CONSIST ALARM ANNUNCIATOR**	-	1	-	-	-	2	8	7.0	7	2-7
BRAKE CONDITION ANNUNCIATORS LIGHTS	-	-	-	1	-	4	7	6.6	7	4-7
TIMER	-	-	-	2	-	1	9	6.8	7	4-7

2. Main reservoir pressure

3. Equalizing reservoir and brake pipe pressure

4. Brake cylinder pressure

5. Emergency brake on indicator

6. Brake pipe venting indicator

7. Consist alarm indicator

8. Speedometer

9. Cab signals

10. Power/drawbar force indicator

11. Timer.

Most of the men were not familiar with the brake flow gauge. A few who were, wanted a caution light adjacent to the gauge. The Chessie men preferred an "IN" scale from one to fifteen with the resolution they are now getting from a new Salen gauge. This gauge gives data in the area where the present gauges now pin at ten. It was understood by the men that the gauge would have an adjustable pointer in addition to the regular pointer to set in the value at which the brake system is fully charged.

There were a wide variety of opinions concerning the cab signals. The Penn Central men are somewhat special in that they have cab signals that are somewhat more elaborate than those found on other properties in most of the United States. The location of the signals and acknowledging devices was the subject of much concern. The signals were downgraded because they did not have enough aspects, and were not centrally located in the cab as they were used to. One man commented that the signals in their present location may be lost in the clutter of displays and therefore, may not be attention-getting enough. A suggestion was made that there should be a device for performing a cab signal test in the cab in addition to the yard test. If such a device were installed it could possibly be connected with an acknowledger. One man suggested that the cab signals could be displayed on the CRT provided.

It was quickly apparent that the engineers missed the signal acknowledger that they were accustomed to. It was generally agreed that an acknowledging device was necessary in locomotive cabs operating where there is automatic train control (ATC). The men had various opinions concerning the location of such a device. Some wanted it located either on the right or the left side of the main control panel. Some thought a foot pedal would suffice. The issue developed, from a human factors standpoint, is that an acknowledger is required in ATC areas to prevent a penalty application of the brake system. The implication for a final design is that the acknowledger

should be integrated rationally with the other display and control devices and not simply placed ad hoc where space happens to be available.

The consist alarm annunciator with reset feature was acceptable. Some men, however, wanted the annunciator light divided into four sections. This was because they wanted to know whether the malfunction was in the first, second, third, fourth and beyond units. In addition, some men expressed a desire to be able to isolate the second through the fourth units from the lead unit.

The brake venting and emergency brake annunciators were acceptable. Most men appreciated the auditory cue associated with the onset of the light. It was also pointed out that the brake venting annunciator would have an associated auditory cue that would remain on as long as the annunciator was on.

Most of the subjects endorsed the idea of the electric timer while some felt it was unnecessary. One man questioned the accuracy of such a device and felt that the engineer would have to calibrate it against his watch much as he calibrates the speedometer today.

The numberless air reservoir gauge elicited mixed opinions among the engineers although it was favorably received. This seemed due to their unfamiliarity with present diesel compressors and the insufficient capacity of the air compressor systems on some electric locomotives; therefore they preferred numbers (absolute value) at both high and low ends of the scale.

There was almost universal acceptance and admiration for the brake pipe pressure/equalizing reservoir vertical scale indicator. Some men questioned the 110 psi high resolution limit and it was pointed out that the indicator was designed for line haul freight use and that today's train air brake systems may be charged up to this value. They pointed out that they run piggyback trains at 100 psi brake pipe pressure.

There was general acceptance of the brake cylinder gauge. Again some men questioned the high upper limit of 120 psi. It was pointed out that some newer locomotives are at 90 psi and that readings higher than that would alert the locomotive crew to improper air hose connections resulting in air from the main reservoir being applied directly to the locomotive brake cylinders.

There was universal acceptance of the speedometer. A suggestion was made that provision be made so the engineer could recalibrate it. Most men expressed dissatisfaction with digital readouts for freight trains although they found them acceptable on metroliners. Some men did not like digital speedometers in any application. This is because digital speedometers are distracting. There is a tendency to look at it more than necessary with the attendant possibility for overcontrolling the train.

The function of the power/drawbar force indicator had been described to the engineers in considerable detail. The lack of numbers of the dial face was discussed and most men did not object. A few suggested numbers 1 through

10 as reference marks. Several men thought the meters should be separate rather than a duplex gauge.

4.3 SECONDARY DISPLAY AND OVERHEAD PANELS

Figures 6 and 7 show the arrangement of the secondary display and overhead panels respectively. The following functions are contained on these panels and the individual ratings shown in Table 6.

Secondary Display Panel

1. Advisory/caution and warning annunciator
2. Communications handset
3. Train handling display.

Overhead Auxiliary Control Panel

1. Dynamic brake cutout
2. Generator field
3. Engine run
4. Fuel pump
5. Ground relay
6. Cab temperature control
7. Class light
8. Traction motors
9. Engine condition
10. MU-2 valve
11. Cutout valve
12. Windshield
13. Exterior lights
14. Headlights

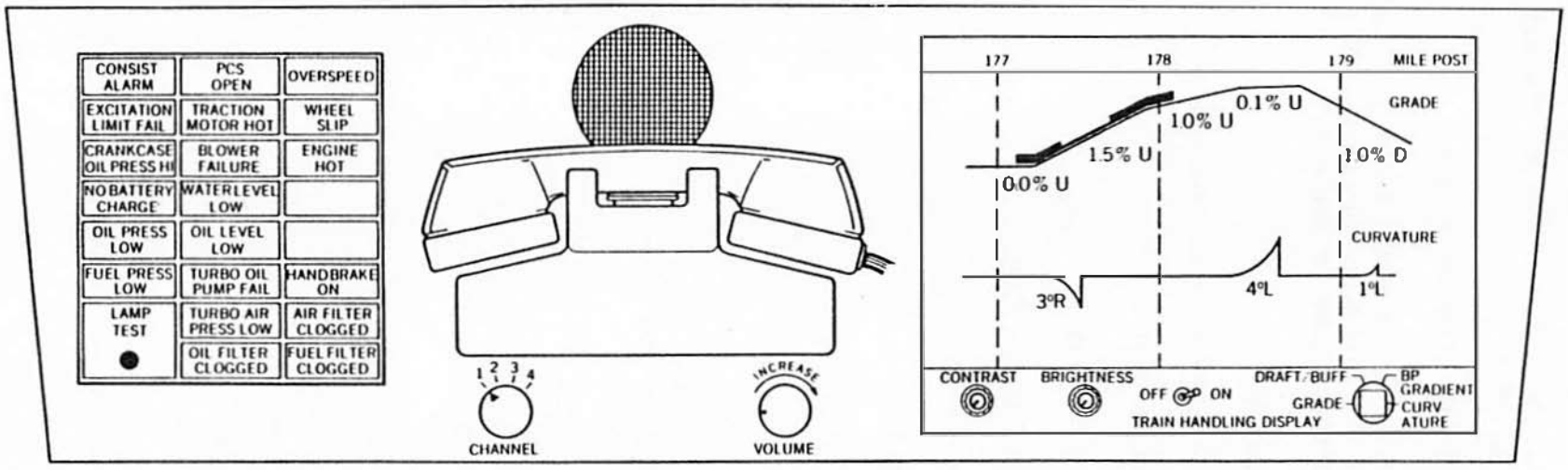

Figure 6. Secondary Display Panel

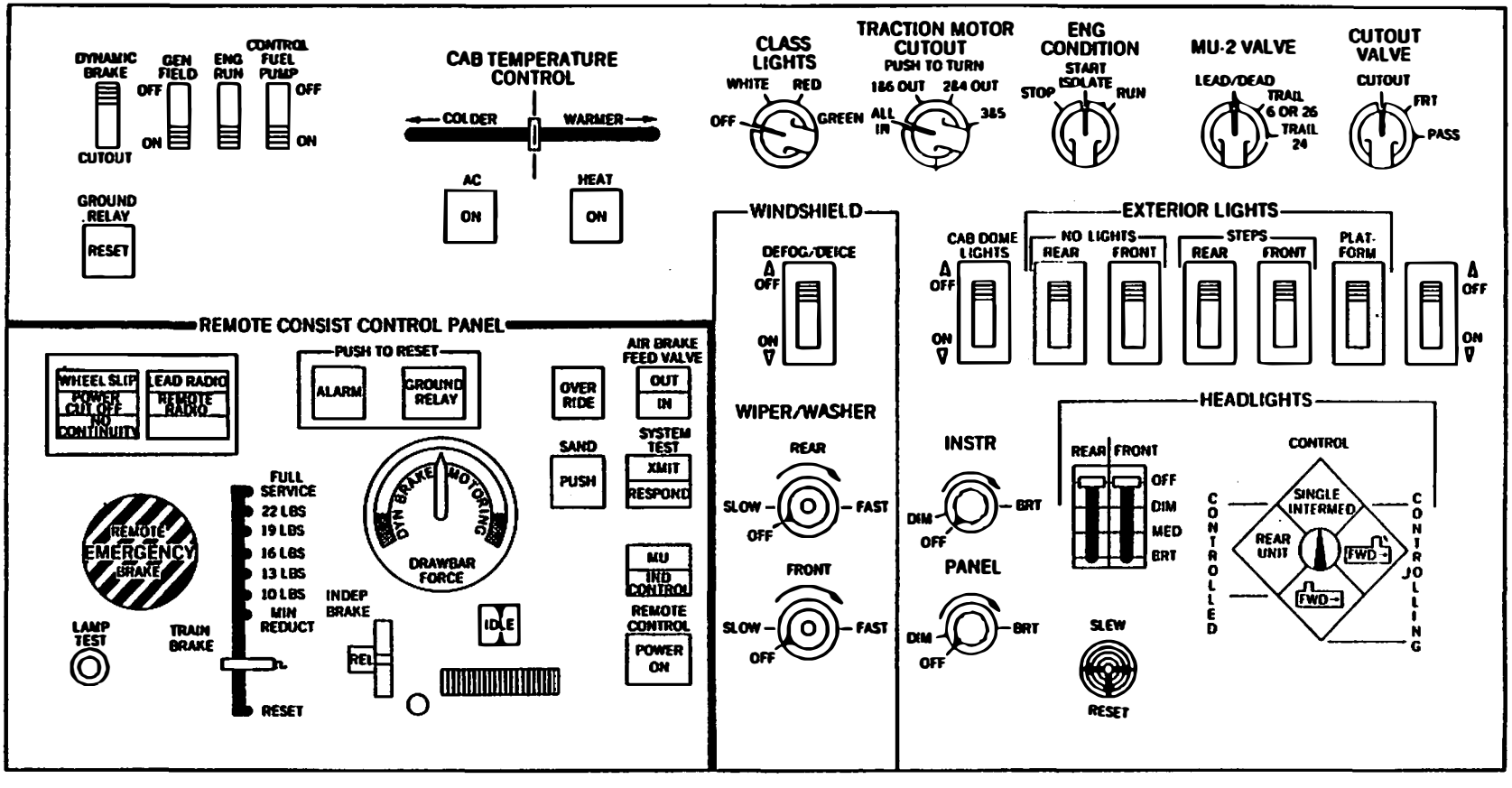

Figure 7. Overhead Auxiliary Control Panel

Table 6.

FEATURE

SECONDARY DISPLAY AND OVERHEAD PANEL

ITEM	RATING							MEDIAN	MODE	RANGE
	1	2	3	4	5	6	7			
RADIO**	-	2	3	2	-	1	4	4.0	7	2-7
TRAIN HANDLING DISPLAY**	-	1	1	1	1	1	7	6.6	7	2-7
ANNUNCIATOR PANEL	-	-	-	-	-	1	10	7.0	7	6-7
OVERHEAD CONTROL PANEL**	-	-	1	1	-	2	8	6.7	7	3-7

15. Panel and instrument lights

16. Remote consist control.

Most of the engineers liked the idea of having all of the annunciators in one location within their field of view. Only one man preferred them on the rear wall where he was accustomed to them. One man had the idea of dividing the functions into three vertical columns. The first column would contain annunciators indicating malfunctions that required almost immediate action such as wheel slip, brake warning, PC light, etc. The second column would cover items possibly requiring a response that would be deferred such as hot engine. The third column would consist of maintenance advisory annunciators signaling malfunctions such as clogged filters. One man thought that the covered maintenance advisory lights should be relocated to a maintenance panel and not be at the engineer's work station at all. The men were queried to determine their attitudes concerning inadvertant movement of the locomotive when the handbrake light is on. Three options were offered to them.

1. Bell sounds when generator field switch is energized

2. Bell sounds when throttle is opened to notch 1 and power is obtained

3. Bell sounds when throttle opened and no power is obtained.

Most of the men when asked this question stated that they preferred that no diesel power be allowed to develop when the handbrake is on. One man wanted a bell to sound when the handbrake is on and the generator field is energized.

Finally, one man suggested that the annunciator panel display all malfunctions for all locomotives in the consist.

The radio was of considerable interest to the men. All of them liked the location but some downgraded it for differing reasons. It was necessary to explain to the men that the cab would be much quieter than the ones they were accustomed to. Therefore, there would be little, if any, ambient noise to interfere with normal communications. If this were the case, the man preferred a push to talk built-in microphone to the present handset because someone always wants to talk during high workload period. It was also pointed out that if a handset was used that it should be on a theft-proof cord such as that found on public telephones. A handset, as shown in the present design, was deemed acceptable for use by other occupants of the cab if necessary. During discussions of railroad communications some men commented on the quite noticeable lack of communications discipline. They felt the radio, in practice, was used like a citizens band and extraneous chit-chat should be eliminated. Many men also felt that only the engineer should have access to the radio. However, when they were reminded that there is a genuine need for other trainmen to have access to the radio in a freight locomotive cab, they agreed that a duplicate radio should be present in the left seat. One man commented that there should be separate passenger and freight channels and disciplined communications channel usage.

A final comment was that the possibility of using a beeper to page the engineer should be explored with a floor mounted push-to-talk control.

The train handling display was unfamiliar to the men. They expressed great interest in its operation, and all felt that they would have to get used to it. Some men felt that it would be useful as a training device but would be turned off when the engineer became familiar with the territory. One man thought the device would be misused by management in that inexperienced men would be expected to use it and rely on it.

The issue was also raised as to why the train handling display couldn't move vertically from bottom to top instead of left to right. Finally, one man noted that the CRT would be a good place to display the cab signals.

The majority of the subjects generally like the overhead control panel. Men who wore bifocal glasses commented that, with the size lettering provided and the lighting, that they had no difficulty reading the panel legends even without their glasses. Most men commented that they wanted the sliding switches turned 180 degrees so that the "ON" position was up rather than down as they are now. Some wanted the headlight dimming function moved from this panel to the main control panel and some wanted a foot button similar to an automobile with an indicator light. They commented that they liked the overhead panel as long as the switches provided were those that seldom have to be used. Some expressed the desire to be able to configure the locomotive rear class lights while seated at the control stand. One man noted that the positions of the dynamic brake cutout switch were reversed. He recommended that all slides switches be in the on or off positions. The men liked the MU-2 set up switch in preference to wordy placards. As the men were not familiar with remote consist operations these functions were not evaluated.

4.4 REVERSE CONTROL PANEL

Figure 8 shows the arrangement of the functions on the reverse control panel. Not shown are a horn and bell mounted on the right side. The functions are listed below and the individual ratings shown in Table 7.

1. Train brake
2. Independent brake
3. Throttle
4. Emergency stop
5. Direction lever
6. Horn
7. Bell
8. Light.

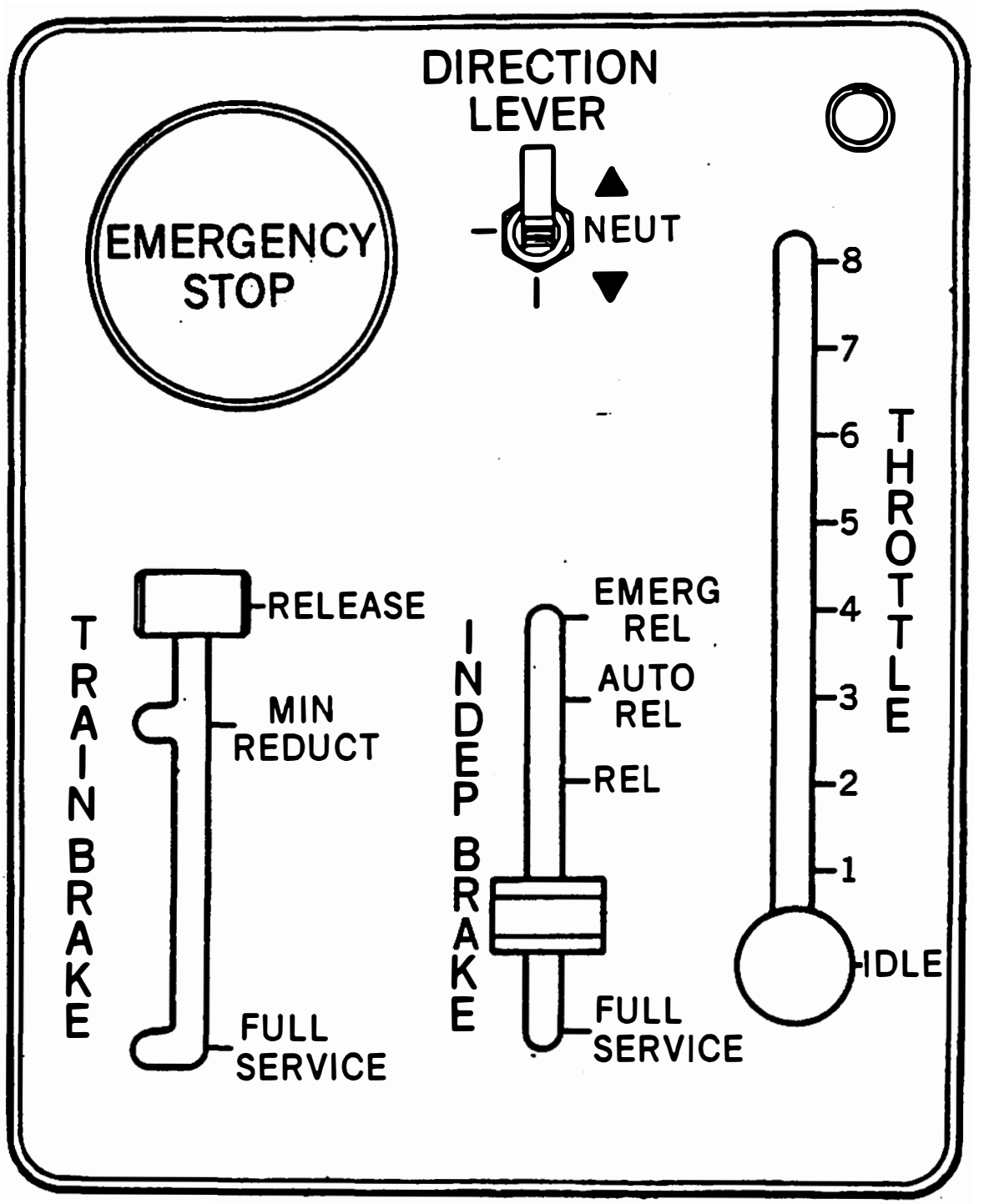

Figure 8. Reverse Control Panel

Table 7.

FEATURE

REVERSE CONTROL PANEL

ITEM	RATING 1	2	3	4	5	6	7	MEDIAN	MODE	RANGE
EMERGENCY STOP PUSHBUTTON**	1	-	-	-	-	1	10	6.9	7	1-7
DIRECTION LEVER**	-	-	1	1	2	2	6	6.5	7	3-7
TRAIN BRAKE CONTROL**	-	-	1	3	-	2	6	6.5	7	3-7
RELEASE DETENT	-	-	-	2	-	2	8	6.7	7	4-7
MINIMUM REDUCTION DETENT	-	-	-	3	-	2	7	6.6	7	4-7
SERVICE RANGE POSITION	-	-	-	3	1	1	7	6.6	7	4-7
FULL SERVICE POSITION	-	-	-	3	-	2	7	6.6	7	4-7
INDEPENDENT BRAKE CONTROL	-	-	-	1	-	2	9	6.8	7	4-7
EMERGENCY RELEASE POSITION**	1	-	-	-	-	2	7	6.8	7	1-7
AUTOMATIC RELEASE POSITION**	2	-	-	-	-	2	6	6.7	7	1-7
RELEASE POSITION	-	-	-	1	-	2	7	6.8	7	4-7
SERVICE RANGE POSITION	-	-	-	1	-	2	7	6.8	7	4-7
FULL SERVICE POSITION	-	-	-	1	-	2	7	6.8	7	4-7
PANEL POWER INDICATOR LIGHT	-	-	-	1	-	2	9	6.8	7	4-7
THROTTLE CONTROL**	1	-	-	1	-	2	8	6.7	7	1-7

The reverse control panel was generally well received. However, some men were concerned that even though the panel was not designed for general main line reverse running, they would be expected to operate the locomotive over an entire division with this panel just because of its presence. The limited operation possible with this panel should preclude such an expectation. Most men felt that the handles were a little small. One man severely downrated the panel because he thought the emergency stop push-botton should be located on the opposite side of the panel. Several men stated that due to the convenient location of main controls, when leaning out the side windown and looking back, the panel was unnecessary. Several men indicated that the automatic release position and the emergency release position were not needed in this application. The same man who noted that the power settings on the main control panel were reversed from what he is accustomed to, downrated the throttle on the reverse control panel for the same reason.

In the event of a failure the functions implemented on the panel should fail safe. The suppression position of the train brake lever is not needed because ATC is inoperative when pushing freight cars.

As stated earlier the movement of the locomotive, particularly in yards, must be accomplished very carefully. While the panel was in use the men were asked if they preferred labels such as forward and reverse in addition to or in place of the lighted arrows. The men could foresee no problems with the arrows alone. However, when given a hand signal to backup - that is move in the direction of the long hood - he pulled the reverser toward him thus initiating movement in the no hood direction. This could be disasterous in an operational situation. Therefore, it should be emphasized at this point that the men must be absolutely familiar with this and any other new device. Moreover, control devices must be designed such that an error is not catastrophic.

4.5 TRAINMAN CONSOLE

Figure 9 shows the functions on the trainmen's (brakeman's) console. The individual ratings are shown in Table 8 and are as follows:

Speedometer Dial	Heating/Air Conditioning Switch
Cab Signal Indicator	Emergency Brake Valve
Lighting Switch	Communications Handset

The speedometer dial at the trainmen's work station was judged by some men to be unnecessary, and therefore, it was downrated. The cab signals elicited much the same comments as those previously noted, and those had to do with concern that they were not correct aspects and not located high in the center of the cab as they were accustomed to.

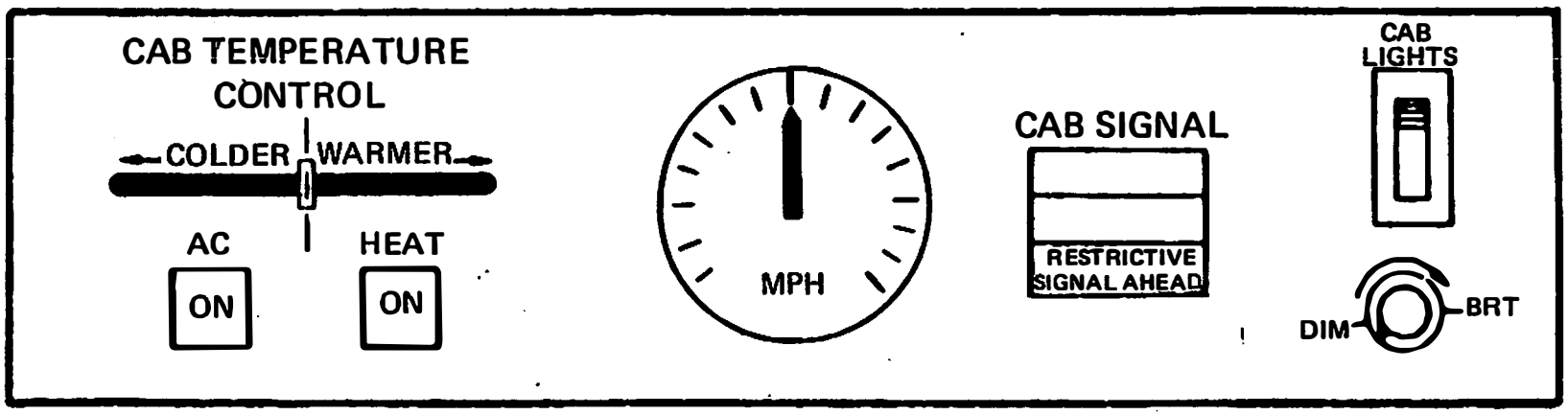

Figure 9. Brakeman's Console

Table 8.

FEATURE

TRAINMAN CONSOLE

ITEM	RATING 1	2	3	4	5	6	7	MEDIAN	MODE	RANGE
SPEEDOMETER DIAL**	2	1	-	1	1	1	6	6.5	7	1-7
CAB SIGNAL INDICATOR**	4	-	2	1	-	-	5	3.5*	7	1-7
LIGHTING SWITCH**	-	1	-	1	1	3	6	6.5	7	2-7
HEATING/AIR CONDITIONING SWITCH*	1	-	-	-	-	1	9	7.0	7	1-7
EMERGENCY BRAKE VALVE	-	-	-	1	-	-	11	6.9	7	4-7
COMMUNICATION HANDSET**	2	1	1	1	-	1	6	6.5	7	1-7

The lighting switch was downrated as being nothing new.

With one exception, all of the men approved the independent heating and air conditioning control at the left-seat work station. The exception preferred that the environmental control be under the sole management of the engineer.

The emergency brake valve (not shown in the figure) was acceptable to all of the man.

The communications handset was discussed previously.

4.6 MOCKUP REAR WALL

Figure 10 shows the mockup rear wall and the ratings of the facilities provided are shown in Table 9.

The men were generally pleased with the cab facilities. The trash container was downrated because some men wanted it located within reach of the engineer. They felt no one would open it in its present location. One man pointed out the importance of designing it for ease of removal to empty it.

The storage compartment was generally acceptable. There was agreement among the men that it should be lighted. The men were divided regarding shelves and cost hooks versus bars and hangers.

The men all liked the lavatory compartment although one man was concerned about the proximity of the fuse panel near a water faucet. The men were assured that the compartment would have a light. One man suggested that toilet seat covers be provided.

The men all liked the food storage refrigerators.

The drinking water compartment provoked some interesting comments. One man thought the door should have a positive lock not a magnetic gasket. Some men felt that a separate water dispenser was unnecessary or even downright undesirable. They would like the water in a container in the refrigerator. The men thought that the container should not be plastic as the flavor of the plastic may be imparted to the water after a period of time. The fusee rack and torpedo holder were generally judged to be in a good location. However, some downrating occurred because some of the men wanted fusees in a dispenser that allowed the crew to see how many remained. One man noted that no provision was made for stowing a red flag.

4.7 EMERGENCY PROVISIONS

Table 10 shows the ratings of the mockup emergency provisions. The two rear doors shown in Figure 10 were very favorably received and no problems were forecast concerning exiting the cab in an emergency situation. One man pointed out that the door mouldings should be rounded to make it easy to sweep out the cab.

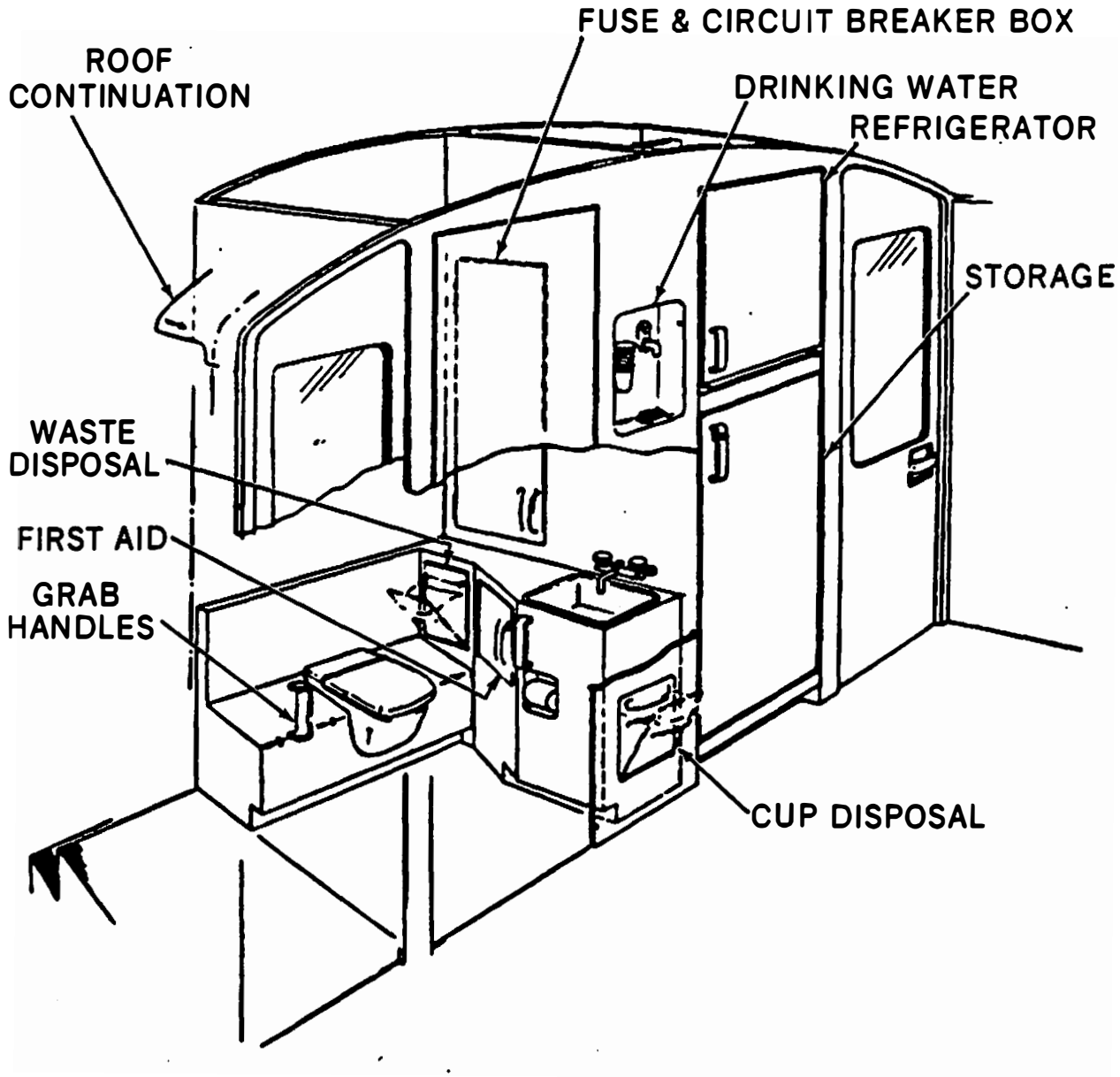

Figure 10. Mockup — Rear Wall

Table 9.

FEATURE

CAB FACILITIES

ITEM	RATING 1	2	3	4	5	6	7	MEDIAN	MODE	RANGE
TRASH CONTAINER**	2	-	1	1	-	1	7	6.6	7	1-7
STOWAGE COMPARTMENT	-	-	-	1	3	2	6	6.5	7	4-7
LAVATORY COMPARTMENT	-	-	-	-	-	1	11	6.9	7	6-7
FOOD STORAGE REFRIGERATOR	-	-	-	-	-	1	11	6.9	7	6-7
DRINKING WATER COMPARTMENT**	1	-	1	2	1	3	4	5.8*	7	1-7
FUSEE AND TORPEDO HOLDER**	-	1	1	1	1	1	7	6.6	7	2-7

Table 10.

FEATURE

EMERGENCY PROVISIONS

ITEM	RATING 1	2	3	4	5	6	7	MEDIAN	MODE	RANGE
REAR DOORS	-	-	-	-	-	2	8	6.9	7	6-7
SIDE WINDOWS**	1	-	-	1	-	1	9	6.8	7	1-7
FRONT WINDSHIELDS**	1	1	-	-	-	1	9	6.8	7	1-7
ROOF HATCH**	1	-	-	-	-	2	8	7.0	7	1-7
FIRE EXTINGUISHER LOCATION**	-	1	-	-	1	2	8	6.7	7	2-7
FIRST AID KIT LOCATION**	-	1	-	1	-	2	8	6.7	7	2-7

The side windows were well received. The low rating was assigned because although the windows are large enough to escape through they were too high from the ground. The concern about jumping from a high place with the potential for serious injury is a very real one.

Most of the men rated the front windshields favorably for escape. Two men were very concerned that the push out feature of these windows would compromise window integrity in the event of an impacting object.

The roof hatch was rated highly by all the men except one who thought that it was unnecessary. It should be noted that the engineers were told that instructions for removing the hatch would be printed both inside and outside of the cab either directly on the hatch or in close proximity.

The location of the recessed fire extinguisher was acceptable although one man did not want it in the cab at all.

Most of the men liked the location of the first aid kit in the lavatory compartment where they felt it was less likely to be stripped. One man wanted it in the cab compartment where the fire extinguisher is located.

4.8 VISIBILITY

Table 11 shows the ratings of the cab windows for visibility. As shown in the table entries the windows were rated favorably for visibility. Several men recognized that although the windows in the rear doors were larger than those found in today's production cabs they were further back and thus the apparent size was the same and rated them accordingly.

When the test plan was written, provision was included to perform a visibility test. It was planned to place simulated visual targets around the cab at various heights and distances to represent the visual environment. This plan was abandoned because the visibility from the mockup was judged vastly superior to that found in today's diesel electrics by experienced railroad personnel who had visited the mockup prior to the test program. This judgment was substantiated by the favorable ratings.

4.9 MISCELLANEOUS

Table 12 shows the individual ratings of the following items:

1. Horn (floor)
2. Horn (reverser)
3. Bell (reverser)
4. Overall mockup rating.

The horn is a floor mounted control positioned for actuation by the engineer's left foot. The horn location was favorably received by most of the men. One man wanted the horn to be hand operated and located on the main

Table 11.

FEATURE

VISIBILITY

ITEM	RATING 1	2	3	4	5	6	7	MEDIAN	MODE	RANGE
LEFT SIDE WINDOW	-	-	-	-	-	1	9	6.9	7	6-7
LEFT FRONT WINDOW	-	-	-	-	-	1	10	7.0	7	6-7
RIGHT FRONT WINDOW	-	-	-	-	-	1	9	6.9	7	6-7
RIGHT SIDE WINDOW	-	-	-	1	-	1	9	7.0	7	4-7
REAR WINDOW	-	-	-	2	-	2	7	7.0	7	4-7

Table 12.

FEATURE

MISCELLANEOUS

ITEM	RATING 1	2	3	4	5	6	7	MEDIAN	MODE	RANGE
HORN** (FLOOR)	-	1	-	2	1	2	6	6.5	7	2-7
HORN (REVERSER)	-	-	-	-	1	2	9	6.8	7	5-7
BELL** (REVERSER)	1	-	-	-	1	2	8	6.7	7	1-7
OVERALL RATING	-	-	-	-	-	4	8	7.0	7	6-7

control panel. Some interesting ideas were discussed concerning this device. Some of the men stated a preference for a two position control that would permit them a high intensity sound or a low intensity sound to be used when passing through residential areas. Some were against this provision. They wanted a single loud position. The men were also divided in their opinions on whether the bell should come on automatically when the horn was turned on or whether they should be independent. One man stated that the locomotive should not be equipped with a bell because a bell does not attract attention; it should be replaced by a very loud unfamiliar siren. Upon questioning many men stated that they would like the horn to come on at the end of the locomotive leading the direction of travel.

One man did not see the need for a bell control on the reverser.

The overall ratings shown in the table reflect the men's opinions of the overall design concept which, as shown in the table, were quite favorable. It is clear at this point that the preliminary mockup evaluation and test program developed a great deal of information and insight into the nuances of a human-factors locomotive cab design that should prove quite valuable during subsequent design development.

5. CONCLUSIONS AND RECOMMENDATIONS

The test results presented in this report should be interpreted and applied very cautiously. The small sample size used precludes generalizations to engineers nationwide. The general lack of familiarity with mountainous terrain and remote controlled slave locomotives should be considered as well as the typical operating environment. It should also be recognized that the mockup evaluation and test program was a very preliminary study with two principal objectives. The first was to gain an understanding of the problems facing the locomotive engineer in a complex modern operating environment in the context of a user evaluation of a potential cab design. The second was to develop a methodology for assessing new cab design concepts and defining problem areas.

Regarding the first point, although the new cab was liked by all the men, it is clear that extensive evaluation by engineers is an essential element in the design process during preliminary design programs. The men were generally enthusiastic and interested in the design. The favorable attitudes and high ratings, however, may be influenced in part by the novelty of the concept and test situation thus generating a halo effect.

This phenomenon is widely recognized in the behavioral sciences and has been extensively discussed in the literature. This phenomenon can be generally defined as a measurable positive change in attitude or behavior as a function of special attention and interest that occurs independently of the specific test situation. The possibility that the halo effect contributed in part to the ratings cannot be discounted in the present study. However, it is concluded that the ratings do reflect real differences in attitudes toward both existing designs and the new design concept. This conclusion is based on the detailed examinations of the comments made concerning the reasons any particular rating was given, either high or low. The men had very logical reasons in most cases.

It should be pointed out, too, that when the engineer assigned a rating to an item the rating was entered on the form by the test conductor. This procedure was followed because it was assumed that it would keep the conversation going which for purposes of the preliminary study was a significant source of information to supplement the absolute value of the assigned rating. However, again a potential bias may have been introduced into the results because it could equally be assumed that had the engineer filled out the rating sheet privately both the ratings and the comments may have been quite different. Although every effort was made to remain objective and keep conditions as constant as possible during the test program the research team was also strongly motivated and deeply interested in the program.

As a final comment on the test procedures it should be noted that the test team was also learning as the evaluations progressed. For this reason a decision was made to avoid being so rigid as to preclude developing new information and modification of procedures if the situation clearly warranted it.

The seating in the mockup consisted of two high back chairs on pedestals that rotated, were adjustable up and down and forward and backward. The armrests could be lowered for quick exit from the chair. These chairs are manufactured by the Freedman Seating Company of Evanston, Illinois. All of the men liked these seats. The seats were not formally evaluated for two reasons. First, the mockup seats used were a test expedient to facilitate the tests. Although they approximated the functional requirements established for seating during design development they were clearly not suitable for the rugged cab environment. Second, the Association of American Railroads was concurrently performing an engineer field evaluation of two seats they have had developed for locomotive cab use. The results of these tests must be awaited prior to making a final determination on a suitable seat.

It is recommended that the mockup evaluation and test program be extended to include a geographically representative sample of personnel, possessing a wide range of operating experience over a variety of train make up, terrain and train handling situations. The test program should also include additional crewmembers such as firemen and brakemen to evaluate the trainman's work station at the left side of the cab. The seven point rating scale should be modified to include items such as pneumatic control valves. In addition, it is recommended that a supplementary questionnaire/survey form be developed. This feature is important because there are significant features of cab functions that do not lend themselves to the rating format but rather to a multiple choice format. For example, the horn button that is now in the cab mockup was rated highly in its present location. However, additional information should be developed - should the horn have two positions - a high intensity position and a low intensity position for use in residential areas - or should it modulate from low intensity to high intensity? The extended mockup testing constitutes a logical extension of the design development process by providing an additional opportunity to perform a design iteration based on a representative sample of user performance and preference. This is important because the design can be easily modified as new functions are recognized on the drawing board prior to commitment to hardware development. A second advantage of extending the test program is to fine tune the cab evaluation techniques so that they could be used during an operational test and provide a tool suitable for predicting operator field performance. Finally, it is recommended that a field survey of engineers be undertaken nationwide. This could be accomplished by visiting all of the Class I railroads with all of the briefing materials used during the present tests plus the revised rating forms and new questionnaire. Groups of engineers would be assembled and the material presented via slides and viewgraphs. They would then be required to fill out the forms. There are two advantages to doing this. The exposure of the concept could be significantly increased very economically and additional inputs could be received by making the same presentation to railway operating officers.

Finally, on the basis of the evaluation and test to date, some preliminary recommendations can be made on modifying the locomotive cab design described in Report No. D339-10017-1, Locomotive Cab Design Development, Volume II,

"Analysis of Cab Environment and Development of Design Alternatives". These recommendations are listed below with a brief statement of the reason for selection.

Main Display Panel

1. The timer should be relocated to the secondary display panel and the cab signals expanded to five larger aspects with a lamp push to test feature. The five signal aspects will fulfill two requirements. First, all of the signaling systems used on major railroads can be accommodated with this design. Second, expansion of the cab signaling display capability provides some designed-in flexibility for assessing new signaling concepts if necessary.

2. A master caution annunciator should be added, located to the upper left of the equalizing reservoir/brake pipe pressure indicator.

3. The air and emergency brake venting annunciators should be located to the left of the equalizing reservoir/brake pipe pressure indicator and centered among the air gauges. This will keep the cab signals and annunciators as separate as practical for maximum discrimination.

Main Control Panel

1. A guarded, lighted pushbutton should be added in the upper left hand corner. This button should be labeled equalizing reservoir. Lifting the latch and depressing the button would allow the equalizing reservoir to bleed to zero. This feature is accomplished in the "HANDLE OFF" position in today's locomotives. The new design does not have this position on the train brake control therefore an additional function is required.

2. The headlight set up control, including dimmer, and headlight slew switch should be relocated from the overhead panel to the left hand side of the main control panel.

3. The throttle/dynamic brake interlock should be changed to an illuminated pushbutton (guarded) and located to the right of the wheel.

4. An acknowledger should be added located near the bottom of the panel and to the right of the throttle/dynamic brake.

5. Two switches should be added near the bell to provide the engineer with selectable options for sounding the horn and bell either independently or together and modulating the horn.

Secondary Display Panel

1. Add timer between caution annunciators and communications set.

2. Convert communications handset to push to talk instead of handset.

Secondary Control Panel

1. Relocate remove control unit from the overhead panel and place next to the primary control panel for ease of use. These are critical controls when this mode of operation is employed. Eliminate the drawbar force indicator. This information is available on the train handling display on the secondary display panel.

2. Add ash tray and permanent clip for paperwork, and recessed coffee cup holder.

3. Provide enhanced lip at bottom to prevent items from rolling off.

Overhead Panel

1. Delete remote control unit.

2. Relocate functions to take advantage of this additional space and reduce panel size.

General Interior

1. Provide light switches at entrances to cab (just inside door) and inside lavatory, storage compartment and cooler.

2. Eliminate water dispenser and make provisions to provide water in containers for storage in the cooler.

3. Move fuse and circuit breaker panel from lavatory to rear wall.

4. Reverse locations of trash container and fuse holder.

5. Extend engineer's footrest the entire length of console and add footrest at trainman's console.

A significant problem area was discovered during the test and evaluation program. The train brake control in the locomotive cab mockup does not have a "HANDLE OFF" position such as is now provided on the standard AAR air brake control stand. When the brake pipe on freight trains is charged to a pressure greater than 80 psi a full service reduction cannot be achieved because brake valves are cammed for a maximum 23 psi reduction in full service regardless of the initial charge in the brake pipe. Full service is defined as the application of the automatic air brake to the point where the auxiliary and brake cylinder pressures are equalized. The following table

shows the relationships between the initial brake pipe pressure (BP), brake pipe reduction (BR) to obtain equalization and service equalization pressure (SEP).

BP (PSI)	BR (PSI)	SEP (PSI)
110	32	78
100	29	71
90	26	64
80	23	57
70	20	50

To achieve an over reduction, that is, brake pipe reductions of 26, 29 and 32 psi with present brake systems, the engineer must place the automatic brake handle in the "HANDLE OFF" position. Most of the northeast corridor engineers who participated in the present investigation had occasion to use this position but did not mind its absence. One engineer had worked freight over the mountain area near Harrisburg and insisted that it be included. The officers from the Chessie System considered the over reduction feature mandatory. The Southern Pacific was queried and replied that they do not recommend the procedure but state how to do it in their operating manual. The real problem seems to be that the present day automatic brake valve, designed in the early 1950's, was set up for a brake pipe charged to 70 psi. At any setting higher than 80 psi the over reduction position is necessary to obtain full equalization since railroads seldom use the 70 psi brake pipe setting today. The trend is toward higher initial settings. The engineer will be required to employ the over reduction position more frequently for initial terminal air brake testing and while negotiating major downgrades.

It is concluded that a new approach is required and therefore the following human factors recommendation is made. Two bugs should be added to the equalizing reservoir/brake pipe pressure indicator as shown in Figure 11. The master bug would be adjustable along the indicator bezel from 70 to 110 psi. By setting the bug at the particular pressure at which the brake pipe is charged, the engineer would initiate a command signal to the air brake circuitry logic to set up for full equalization according to the table presented above. In the sketch the master bug is set at 80 psi. The slave bug shown in the sketch is linked to the master bug and moves with it. It indicates the service equalization pressure which in the example is 57 psi. Full service equalization would always be achieved regardless of the initial brake pipe pressure setting when the train brake is placed in the full service position.

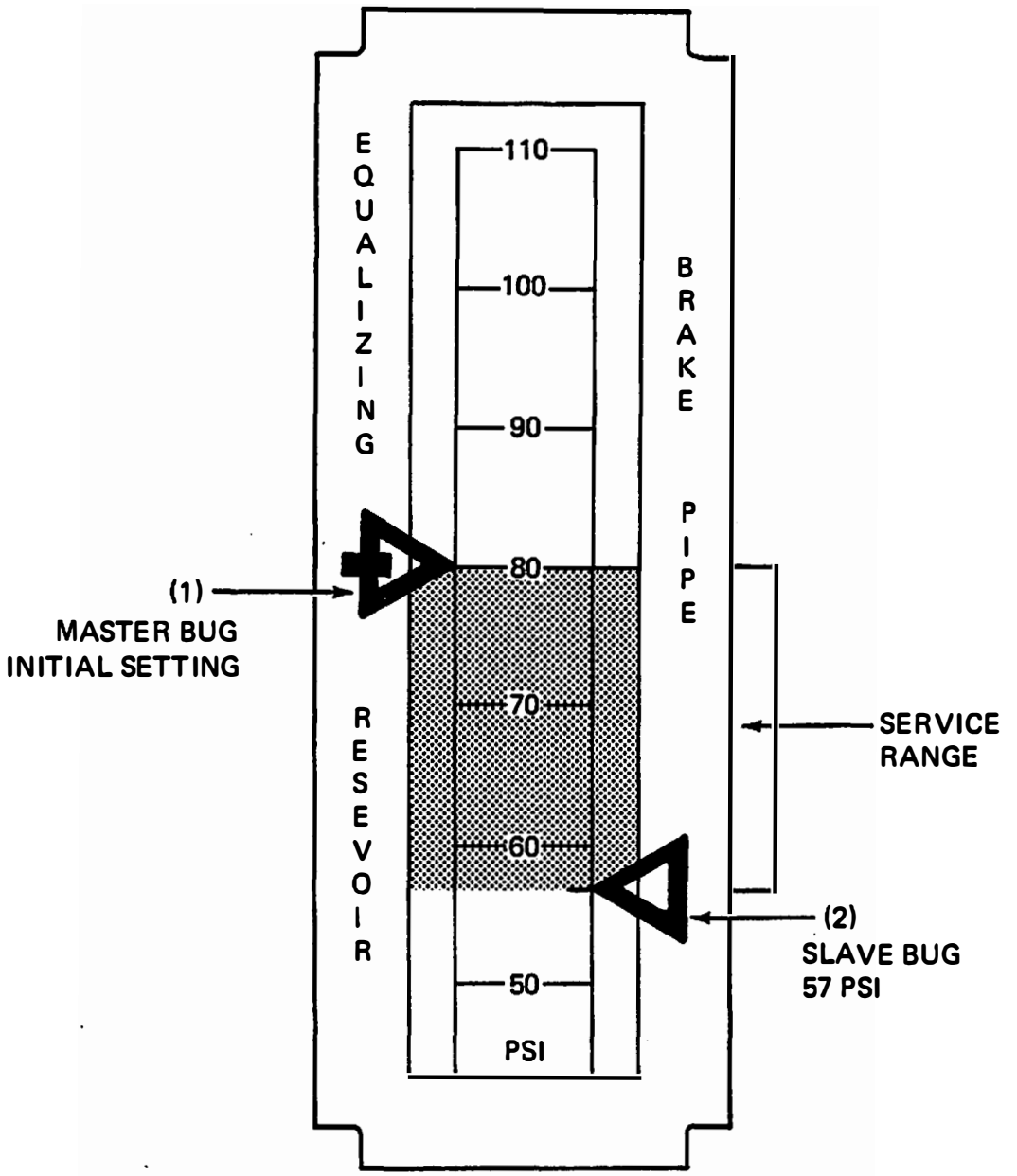

Figure 11. Automatic Brake Pressure Compensator

The slave would track the master in 7 psi increments or decrements for every 10 psi change in pressure setting. This concept is additionally attractive from a human factors standpoint because the service range is clearly delineated between the two bugs and therefore directs the engineers attention to the appropriate place to monitor his control inputs.

This is shown by the shaded area in the sketch and will vary in magnitude as a function of the setting. Further research will be required of this concept from human factors, safety, cost, and reliability engineering disciplines.

APPENDIX A

PERFORMANCE TEST PLAN

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15. Supplementary Notes

16. Abstract

This document presents the performance test plan proposed for the evaluation of the full scale mockup developed under Contract DOT/TSC 913. The performance tests will be used to demonstrate that the locomotive cab meets or exceeds all human factors criteria for work station design, habitability and occupant protection. The complete analysis will provide a preliminary verification of the system functional analysis, identify problem areas, obtain experience in locomotive cab assessment and provide suggestions and generate hypotheses for further research and development.

17. Key Words	18. Distribution Statement
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1. INTRODUCTION

DOT/TSC is funding a program to design and develop a modern cab for line haul freight locomotives. A full scale mockup of the locomotive cab was built. The mockup will be used to demonstrate that the cab meets or exceeds all human factors criteria for work station design, habitability and occupant protection and that all functional requirements are met. The mockup tests are a logical extension of the design development process. It is the first opportunity to perform a design iteration based on an analysis of user performance and preference. This is important because, if design deficiencies exist or additional concepts need to be tried, modifications to the design can be made and evaluated using partial simulation techniques prior to committing to a prototype cab. The second purpose of the test program is to gain experience in the techniques of cab evaluation. Preliminary data will be refined and approaches developed that could be applied in a dynamic or operational test environment.

A mockup evaluator and data form were devised. Their purpose is to provide a standardized format for eliciting the engineer's opinions and recording the data. The data will be used to troubleshoot the design, identify problem areas, take corrective action where appropriate, and gain some preliminary understanding of cab evaluation techniques.

2. TEST SITE

The mockup evaluation will be conducted at Boeing Vertol. The mockup will be mounted on a wooden platform ten feet wide, twenty feet long and five high to locate it at the proper operational height above the rails. A sketch of the mockup mounted on the platform is shown in Figure A-1.

The platform will be placed over a section of track located within the Boeing Vertol facility, as shown in Figure A-2 to provide some visual realism.

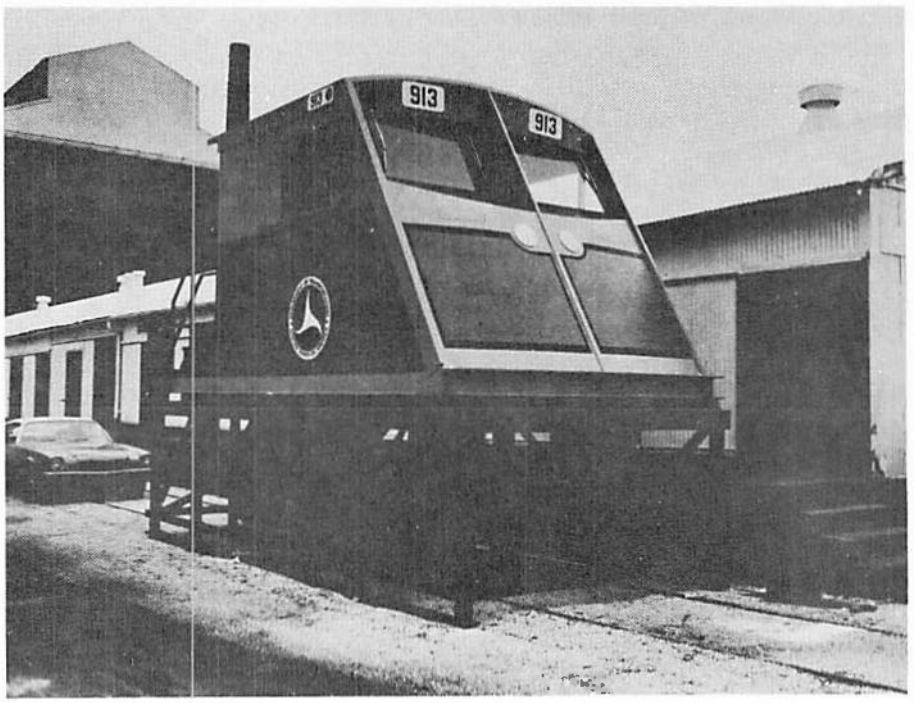

Figure A–1. Mockup Installation

Figure A–2. View from Engineer's Seat

3. PERSONNEL

The Penn Central Transportation Company has provided Boeing Vertol with a list of twelve qualified enginmen who have expressed interest in participating in the program. These are all highly qualified enginmen who presently operate or supervise trains in high-speed passenger service in the Northeast Corridor. They represent a cross section of enginmen from as far north as the New Haven Line, Harrisburg District, Washington, New York and Philadelphia. Some of the individuals listed are officers of the Union as well as enginemen and others are officers of the Company. Although the number is small from a statistical standpoint it should be sufficient for the initial preliminary evaluation due to the high levels of experience represented by the participants.

4. METHOD

The preliminary assessment of the locomotive cab mockup will be done in the following sequence:

1. Pretest briefing
2. Test and evaluation
3. Post-test debriefing.

4.1 PRETEST BRIEFING

The engineer will be briefed upon arrival at the test site. The briefing will cover three areas:

1. Introduction
2. Familiarization with mockup concepts
3. Test instructions.

4.1.1 Introduction

The introduction will be structured to orient the engineman to the locomotive cab development program. To provide an appropriate test response set, it will be explained that the new cab design is being developed as part of a research program to evaluate new concepts in display/control design, operating procedures and general working and living environment. It will be emphasized that the engineman is not the object of the test and that it is his experience in existing cabs that provide the necessary expertise to further develop the design concept along realistic lines. He will be encouraged to consider that some day he may have to operate a locomotive from a new cab derived from the present design and therefore to be candid during his critique.

4.1.2 Familiarization with Mockup Concepts

The second part of the prebriefing will consist of an introduction to the new design concept. Briefing materials will be prepared and will include photographs, sketches and the Operator's Manual. The engineman's attention will be directed to the similarities and differences between the new design and cabs he is accustomed to.

4.1.3 Test Instructions

The third part of the prebriefing will consist of an explanation of the test instructions. The engineman will be instructed to inspect all of the mockup features. He will be required to perform the procedures contained in the operator's manual; that is, pre-run, running and post-run procedures. Upon completion of the mockup inspection and

procedural review, the engineman will be given a rating scale for evaluation of the cab features. (The scale is discussed in Section 4.2.2.) The features to be evaluated have been organized into the following categories:

a. Main control panel
b. Main display panel
c. Secondary display panel
d. Annunciator panel
e. Overhead panel
f. Remote control panel
g. Reverse control panel
h. Left seat controls and displays
i. Cab facilities
j. Emergency provisions
k. Visibility
l. Seating

The ratings will be done in the mockup to provide the engineman the opportunity for more detailed inspection of a feature before assigning a rating.

4.2 TEST CONDITIONS

Two test conditions will be employed. These are:

1. Visibility test
2. Mockup evaluator

4.2.1 External Visibility

External visibility from the cab mockup will be assessed by placing visual targets at various heights and distances around the cab. The engineer will be instructed to observe the visual field as he normally does and report the location of each target. The targets will be selected and located in a manner that is representative of the railroad environment. The test conductor will record the number and location of detected targets.

4.2.2 Mockup Evaluator

A mockup evaluator was prepared to standardize the evaluation as shown in the following pages. The evaluator will be used as an instrument to gather the information based upon which subsequent analysis will be made. The evaluator form is in three parts: The mockup item to be rated, a rating scale and a place for the engineman to explain why a particular rating was assigned. The rating scale is a seven point scale where a 1 on the scale means very hard to use while 7 indicates very easy to use. As a benchmark, the engineman will be instructed to

assign a rating with respect to typical cabs he is used to. After assigning a rating, the engineman will be instructed to explain why he assigned that particular rating in the comment column of the evaluator.

The engineman will be asked to make a final overall evaluation after completing the detailed evaluation. Employing the same seven point scale he will be asked to rate the overall cab with respect to what he is used to.

4.2.3 Debriefing

Upon completion of the mockup ratings the engineman will be debriefed. He will be provided the opportunity to critique the design approach in its broader aspects, suggest improvements in the present design and areas where further investigation may be required.

CAB MOCKUP
EVALUATION FORM

Weight	Height	Age	Glasses
_____	_____	_____	_____

Years of Experience as an Engineman: _____

Locomotive Experience

GE	GM	Other

Test Director _____ Date _____

MAIN CONTROL PANEL ITEM	RATING	COMMENT
1. Manual Sand Pushbotton	1 2 3 4 5 6 7	
2. Train Brake Lever	1 2 3 4 5 6 7	
3. Reset Position	1 2 3 4 5 6 7	
4. Release Position	1 2 3 4 5 6 7	
5. Minimum Reduction Position	1 2 3 4 5 6 7	

MAIN CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
6. Service Range Position	1 2 3 4 5 6 7	
7. Full Service Position	1 2 3 4 5 6 7	
8. Suppression Position	1 2 3 4 5 6 7	
9. Independent Brake Lever	1 2 3 4 5 6 7	
10. Emergency Release Position	1 2 3 4 5 6 7	

MAIN CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
11. Automatic Release Position	1 2 3 4 5 6 7	
12. Release Position	1 2 3 4 5 6 7	
13. Full Service Position	1 2 3 4 5 6 7	
14. Stop All Engines Pushbutton	1 2 3 4 5 6 7	
15. Interlock Pushbutton	1 2 3 4 5 6 7	

MAIN CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
16. Reverse Control Panel Pushbutton Switch	1 2 3 4 5 6 7	
17. Throttle Dynamic Brake Handwheel	1 2 3 4 5 6 7	
18. Idle Position	1 2 3 4 5 6 7	
19. Power Settings	1 2 3 4 5 6 7	
20. Dynamic Brake Settings	1 2 3 4 5 6 7	

MAIN CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
21. Set Up Position	1 2 3 4 5 6 7	
22. Dynamic Brake Settings	1 2 3 4 5 6 7	
23. Direction Lever	1 2 3 4 5 6 7	
24. Forward Position	1 2 3 4 5 6 7	
25. Neutral Position	1 2 3 4 5 6 7	

MAIN CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
26. Reverse Position	1 2 3 4 5 6 7	
27. Emergency Stop Button	1 2 3 4 5 6 7	
28. Bell Pushbutton	1 2 3 4 5 6 7	
29. Console Lock Pushbutton	1 2 3 4 5 6 7	
30. Feed Valve Knobs	1 2 3 4 5 6 7	

MAIN DISPLAY PANEL ITEM	RATING	COMMENT
1. Brake Pipe Air Flow Dial	1 2 3 4 5 6 7	
2. Main Reservoir Pressure Dial	1 2 3 4 5 6 7	
3. Equalizer Reservoir Pressure/Brake Pipe Pressure Vertical Scale	1 2 3 4 5 6 7	
4. Brake Cylinder Pressure Dial	1 2 3 4 5 6 7	
5. Brake Condition Annunciators Lights	1 2 3 4 5 6 7	

MAIN DISPLAY PANEL (Cont'd) ITEM	RATING	COMMENT
6. Speedometer Dial	1 2 3 4 5 6 7	
7. Cab Signals	1 2 3 4 5 6 7	
8. Power/Drawbar Force Dual Pointer Dial	1 2 3 4 5 6 7	
9. Timer	1 2 3 4 5 6 7	
10. Start Pushbutton	1 2 3 4 5 6 7	

MAIN DISPLAY PANEL (Cont'd) ITEM	RATING	COMMENT
11. Stop Pushbutton	1 2 3 4 5 6 7	
12. Reset Function to Zero. Elapsed Time Readout	1 2 3 4 5 6 7	
13. Miles Entry	1 2 3 4 5 6 7	
14. Speed Readout	1 2 3 4 5 6 7	
15. Consist Alarm Annunciator	1 2 3 4 5 6 7	

SECONDARY DISPLAY PANEL ITEM	RATING	COMMENT
1. Radio	1 2 3 4 5 6 7	
2. Channel Selector	1 2 3 4 5 6 7	
3. Volume Switch	1 2 3 4 5 6 7	
4. Handset	1 2 3 4 5 6 7	
5. Train Handling Display	1 2 3 4 5 6 7	

SECONDARY DISPLAY PANEL (Cont'd) ITEM	RATING	COMMENT
6. Grade Display	1 2 3 4 5 6 7	
7. Draft/Buff Display	1 2 3 4 5 6 7	
8. Brake Pipe Pressure Gradient Display	1 2 3 4 5 6 7	
9. Curvature Display	1 2 3 4 5 6 7	
10. ON-OFF Switch	1 2 3 4 5 6 7	

SECONDARY DISPLAY PANEL (Cont'd) ITEM	RATING	COMMENT
11. Contrast Control	1 2 3 4 5 6 7	
12. Brightness Control	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	

ANNUNCIATOR PANEL ITEM	RATING	COMMENT
1. Traction Motor Hot	1 2 3 4 5 6 7	
2. Wheel Slip	1 2 3 4 5 6 7	
3. Overspeed	1 2 3 4 5 6 7	
4. Excitation Limit Fail	1 2 3 4 5 6 7	
5. Pneumatic Control Switch Open	1 2 3 4 5 6 7	

ANNUNCIATOR PANEL (Cont'd) ITEM	RATING	COMMENT
6. Crankcase Oil Pressure High	1 2 3 4 5 6 7	
7. Engine Hot	1 2 3 4 5 6 7	
8. No Battery Charge	1 2 3 4 5 6 7	
9. Oil Level Low	1 2 3 4 5 6 7	
10. Blower Failure	1 2 3 4 5 6 7	

ANNUNCIATOR PANEL (Cont'd) ITEM	RATING	COMMENT
11. Fuel Pressure Low	1 2 3 4 5 6 7	
12. Oil Pressure Low	1 2 3 4 5 6 7	
13. Turbo Oil Pump Fail	1 2 3 4 5 6 7	
14. Water Level Low	1 2 3 4 5 6 7	
15. Hand Brake	1 2 3 4 5 6 7	

ANNUNCIATOR PANEL (Cont'd) ITEM	RATING	COMMENT
16. Lamp Test Pushbutton	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	

OVERHEAD CONTROL PANEL ITEM	RATING	COMMENT
1. Dynamic Brake Cutout Switch	1 2 3 4 5 6 7	
2. Generator Field Switch	1 2 3 4 5 6 7	
3. Engine Run Switch	1 2 3 4 5 6 7	
4. Fuel Pump Switch	1 2 3 4 5 6 7	
5. Ground Relay Reset Pushbotton	1 2 3 4 5 6 7	

OVERHEAD CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
6. Cab Temperature Control Switch	1 2 3 4 5 6 7	
7. Air Conditioner Push button	1 2 3 4 5 6 7	
8. Heat Push button	1 2 3 4 5 6 7	
9. Class Lights Selector	1 2 3 4 5 6 7	
10. Traction Motor Cutout Switch	1 2 3 4 5 6 7	

OVERHEAD CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
11. Engine Condition Switch	1 2 3 4 5 6 7	
12. MU-2 Valve Switch	1 2 3 4 5 6 7	
13. Cutout Valve Switch	1 2 3 4 5 6 7	
14. Windshield Defog/Deice Switch	1 2 3 4 5 6 7	
15. Windshield Wiper/Washer Control	1 2 3 4 5 6 7	

OVERHEAD CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
16. Cab Dome Light Switch	1 2 3 4 5 6 7	
17. Number Lights Switches	1 2 3 4 5 6 7	
18. Step Light Switches	1 2 3 4 5 6 7	
19. Platform Lights Switch	1 2 3 4 5 6 7	
20. Spare Switch	1 2 3 4 5 6 7	

OVERHEAD CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
21. Instrument Light Switch	1 2 3 4 5 6 7	
22. Panel Light Switch	1 2 3 4 5 6 7	
23. Headlight Control Switch	1 2 3 4 5 6 7	
24. Headlight MU Set-up Switch	1 2 3 4 5 6 7	
25. Headlight Slew Switch	1 2 3 4 5 6 7	

REMOTE CONTROL PANEL ITEM	RATING	COMMENT
1. Wheelslip Indicator	1 2 3 4 5 6 7	
2. Power Cutoff Indicator	1 2 3 4 5 6 7	
3. No Continuity Indicator	1 2 3 4 5 6 7	
4. Lead Radio Indicator	1 2 3 4 5 6 7	
5. Remote Radio Indicator	1 2 3 4 5 6 7	

REMOTE CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
6. Helper Emergency Brake	1 2 3 4 5 6 7	
7. Lamp Test Push button	1 2 3 4 5 6 7	
8. Train Brake Lever	1 2 3 4 5 6 7	
9. Independent Brake Thumberwheel	1 2 3 4 5 6 7	
10. Alarm Lighted Pushbutton	1 2 3 4 5 6 7	

REMOTE CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
11. Ground Relay Lighted Pushbutton	1 2 3 4 5 6 7	
12. Drawbar Force Dial	1 2 3 4 5 6 7	
13. Interlock Pushbutton	1 2 3 4 5 6 7	
14. Throttle Wheel	1 2 3 4 5 6 7	
15. Override Push button	1 2 3 4 5 6 7	

REMOTE CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
16. Sand Pushbutton	1 2 3 4 5 6 7	
17. Air Brake Feed Valve Pushbutton	1 2 3 4 5 6 7	
18. System Test Pushbutton	1 2 3 4 5 6 7	
19. MU/IND Control Pushbutton	1 2 3 4 5 6 7	
20. Panel Power Pushbutton	1 2 3 4 5 6 7	

REVERSE CONTROL PANEL ITEM	RATING	COMMENT
1. Emergency Stop Pushbutton	1 2 3 4 5 6 7	
2. Direction Lever	1 2 3 4 5 6 7	
3. Train Brake Control	1 2 3 4 5 6 7	
4. Release Dent	1 2 3 4 5 6 7	
5. Minimum Reduction Detent	1 2 3 4 5 6 7	

REVERSE CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
6. Service Range Position	1 2 3 4 5 6 7	
7. Full Service Position	1 2 3 4 5 6 7	
8. Independent Brake Control	1 2 3 4 5 6 7	
9. Emergency Release Position	1 2 3 4 5 6 7	
10. Automatic Release Position	1 2 3 4 5 6 7	

REVERSE CONTROL PANEL (Cont'd) ITEM	RATING	COMMENT
11. Release Position	1 2 3 4 5 6 7	
12. Service Range Position	1 2 3 4 5 6 7	
13. Full Service Position	1 2 3 4 5 6 7	
14. Panel Power Indicator Light	1 2 3 4 5 6 7	
15. Throttle Control	1 2 3 4 5 6 7	

LEFT SEAT CONTROLS AND DISPLAYS (Cont'd) ITEM	RATING	COMMENT
6. Communication Handset	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	

LEFT SEAT CONTROLS AND DISPLAYS ITEM	RATING	COMMENT
1. Speedometer Dial	1 2 3 4 5 6 7	
2. Cab Signal Indicator	1 2 3 4 5 6 7	
3. Lighting Switch	1 2 3 4 5 6 7	
4. Heating/Air Conditioning Switch	1 2 3 4 5 6 7	
5. Emergency Brake Valve	1 2 3 4 5 6 7	

CAB FACILITIES ITEM	RATING	COMMENT
1. Trash Container	1 2 3 4 5 6 7	
2. Stowage Compartment	1 2 3 4 5 6 7	
3. Lavatory Compartment	1 2 3 4 5 6 7	
4. Food Storage Refrigerator	1 2 3 4 5 6 7	
5. Drinking Water Compartment	1 2 3 4 5 6 7	

913 CAB MOCKUP EVALUATOR

CAB FACILITIES (Cont'd) ITEM	RATING	COMMENT
6. Fuse and Torpedoe Holder	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	

EMERGENCY PROVISIONS ITEM	RATING	COMMENT
1. Rear Doors	1 2 3 4 5 6 7	
2. Side Windows	1 2 3 4 5 6 7	
3. Front Windshields	1 2 3 4 5 6 7	
4. Roof Hatch	1 2 3 4 5 6 7	
5. Fire Extinguisher Location	1 2 3 4 5 6 7	

913 CAB MOCKUP EVALUATOR

EMERGENCY PROVISIONS (Cont'd) ITEM	RATING	COMMENT
6. First Aid Kit Location	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	

VISIBILITY ITEM	RATING	COMMENT
1. Left Side Window	1 2 3 4 5 6 7	
2. Left Front Window	1 2 3 4 5 6 7	
3. Right Front Window	1 2 3 4 5 6 7	
4. Right Side Window	1 2 3 4 5 6 7	
5. Rear Window	1 2 3 4 5 6 7	

913 CAB MOCKUP EVALUATOR

SEATING ITEM	RATING	COMMENT
1. Seat Rotation	1 2 3 4 5 6 7	
2. Seat Comfort	1 2 3 4 5 6 7	
3. Seat Adjustment	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	
	1 2 3 4 5 6 7	

5. ANALYSIS

There are some inherent limitations to the methodological scope of the proposed evaluation. Some of the most serious of these will be discussed. The first limitation is the nature of the sample. It is reasonable to assume that the proposed sample will be neither random nor stratified. To provide a random sample, Penn Central would have to select engineers from a table of random numbers. This is often impractical in an applied human engineering investigation. To provide a stratified sample based on such factors as age, experience, size and proficiency would require a larger number of test subjects than is now contemplated.

It should also be recognized that not only will the Penn Central engineers possibly not be truly representative of all Penn Central engineers but may not resemble freight engineers working on other railroads in various parts of the country. This is true because railroads operate under different rules, terrains, and with quite diverse equipment and appurtenances. For example, it is likely that many Penn Central engineers will be unfamiliar with dynamic braking or radio controlled remote locomotive consists. Turns on the Penn Central right of way are in some cases quite sharp and grade crossings frequent. On the other hand, on a railroad such as the Southern Pacific, for example, the engineer may set his throttle in notch 8 and have very few other tasks to do for periods up to six hours. Therefore, interpretations of the results will be offered with considerable caution as to their potential for generalization to the engineer population at large.

5.1 EVALUATOR

To accomplish the human factors analysis of the rating data a series of preference profiles will be constructed along the example shown in Figure A-3. Each subsystem will be represented by a matrix. The features evaluated in each subsystems will be listed in order as determined by the system functional analysis. Entries in the matrix are the number of engineers selecting a particular descriptive category.

For example, the first item in the subsystem was rated very easy to use by all engineers, the third item was rated evenly across categories, and the fifth factor judged very difficult to use. Casting the data in this will permit (a) a preliminary analysis to determine if the functional requirements are met, and (b) that good human engineering design criteria have been applied. It is assumed that if all entries, for example, fall into Columns 6 and 7 that the functional requirements have generally been met and implemented with a good human engineering design. A distribution such as that shown in item 3 will be examined to determine if the functional

Subsystem	Rating						
Item	1	2	3	4	5	6	7
1	-	-	-	-	-	-	X
2	-	-	-	-	-	X	X
3	X	X	X	X	X	X	X
4	X	X	-	-	-	-	-
5	X	-	-	-	-	-	-

Figure A—3. Sample Preference Profile

requirements are not met or if poor human factors design is influencing the engineer's judgment. A distribution such as that shown next to items 4 and 5 will beinterpreted to indicate that the functional requirements were not met and therefore there are serious defects in the human factors design.

To determine whether the downgrade is due to failure to meet the functional requirements or poor design or both, a content analysis will be performed on the comments made in Column 3. That is, comments will be classified and compared to the engineer's rating of a mockup feature. A final analysis will be performed to evaluate the effects of age and experience on the engineer's judgment.

5.2 VISIBILITY ANALYSIS

Data obtained from the target detection test will be used to identify blind spots that occur due to the intrusion of cab structures into the visual field, such as collision posts. Where modification of structure is impractical an appropriate observing procedure will be developed to provide appropriate fields of view.

The completed analysis will provide a preliminary check on the completeness of the functional analysis, problem areas where the present design could be improved, experience in cab mockup assessment techniques, and suggestions for further research and development.

APPENDIX B
REPORT OF INVENTIONS

An inovative device for inclusion in the locomotive brake control system is identified on pages 44 through 47. Patent application has been initiated under the title Automatic Brake Pressure Compensator.

There are no other inovative discoveries, improvements or inventions associated with the program during this phase, nor were any new techniques utilized in the conduct of the test.