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LOCOMOTIVE CAB DESIGN DEVELOPMENT
Volume I: Analysis of Locomotive Cab Environment & Development of Cab Design Alternatives

J. Robinson
D. Piccione
G. Lamers

Boeing Vertol Company
P.O. Box 16858
Philadelphia PA 19142

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INTERIM REPORT

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16. Abstract

This report presents an analysis of the line haul freight engineer's working and living environment, the resultant locomotive cab design and design alternatives. The analysis is based on a delineation of functional requirements found in current line haul operations together with those additional requirements which could arise during the next 10-15 years. The recommended design is the result of a detailed human factors engineering analysis of these requirements according to state-of-the-art criteria and system design practices. Substantial engineering analysis was devoted to the recommended design; this included disciplines of cost, occupant protection, component and subsystem reliability, and system safety analysis.

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PREFACE

The locomotive cab designs described in this report were developed by Boeing Vertol under the sponsorship of the Transportation Systems Center (TSC) for the Department of Transportation, Federal Railroad Administration (FRA). The objective of this work is to develop a locomotive cab design through a human factors systems analysis of the functional requirements of train handling leading to specifications suitable for the development of a cab which is in concert with all operational and safety concerns.

The authors would like to acknowledge the contributions of Dr. John Jankovich, the contract technical monitor, and Dr. Donald Devoe of the Transportation Systems Center; Mr. William McLean, Boeing Vertol Company Surface Transportation Systems Manager of Research and Development; and Mr. Norman Macdonald of the Electro-Motive Division of General Motors, principal subcontractor during the study.

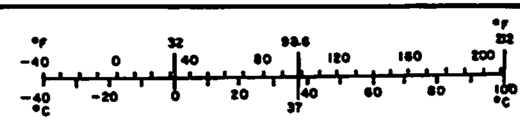
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

The purpose of contract DOT/TSC-913 is to develop a locomotive cab design based on the operator's functional requirements in train operation. The design is predicated on human engineering and other engineering disciplines leading to specifications which are suitable for the design, development, test and evaluation of a cab that is in concert with all operational and safety conditions. The locomotive cab design is based on the most complex set of functional requirements, which are, as anticipated, based on line-haul operational needs.

This report presents an analysis of the line-haul freight engineer's working and living environment and the resultant locomotive cab design and design alternatives. The analysis is based on a delineation of functional requirements inherent in contemporary line-haul operations together with those additional situations which might conceivably arise during the next 10-15 years. The recommended design is the result of a detailed human factors engineering analysis of these requirements in accordance with state-of-the-art criteria in railroad operations and system design practices. The technical content is presented in the following sections and a summary is presented below.

First, however, it is appropriate to offer a brief description of the freight engineer's working environment to place the analysis in perspective.

Today's locomotive engineers are, and will, at least in the foreseeable future, continue to be exposed to a wide variety of assignments. Each task has its own peculiar set of train handling requirements. The economics of train makeup and manpower utilization may dictate, on the one hand, the employment of longer and heavier trains traveling at slower speeds, while on the other hand, short, fast trains which run at frequent intervals appear to hold some promise for the economical movement of produce and merchandise. Locomotive consists are getting longer because trains are heavier and need more tractive effort. Locomotives may be inserted in the train at critical points as helper units, operating either remotely from the front of the train or manned. The trains themselves are usually made up of a mix of loads and mass distribution in combinations of old and new cars as the result of destination blocking. (Track train dynamics blocking is receiving serious attention as an alternative and may become more commonplace in the future.)

Moreover, there is a wide variety of locomotives currently in use, varying from yard switcher, through general-purpose road switchers, to high-horsepower line-haul. Collectively, these represent a wide range of handling differences for the locomotive engineer because of age, horsepower, condition, manufacturer, property specifications, and to some extent, cab layout and available equipment. It has been estimated that today's engineer could conceivably be required to operate in as many as several dozen different locomotives from a large yard, during any given month.

Locomotive engineers also encounter a variety of complex train-handling problems which require considerable skill to solve. The train-handling problems are complex because the engineers must monitor and control several variables at a time. These variables may be presented in analog or discrete form. This process can be described in control-system terms: that is, the engineering is a nonlinear operator in a multiloop feedback system wherein he is required to process information and act appropriately to achieve a desired system output. The feedback loops may be closed (analog) or open (discrete). In a closed-loop system, the engineer controls the output of the system as a direct and continuous function of information feedback. In open-loop systems (discrete) control inputs are not directly affected by feedback.

For example, the engineer has to monitor speed, drawbar force, traction motor load and brake pipe pressure, each of which provides direct feedback by means of appropriate cab indicators of the locomotive and train status. Block signals, track signals and track condition, on the other hand, are discrete indicators that affect systems-control inputs. The engineer makes his control inputs by adjusting the throttle, applying sand to the rails, using dynamic braking, utilizing brake pipe pressure, and regulating the locomotive brakes.

Although the engineer may have traveled over a particular route to the extent that he knows the location of each mile post and the identity of every terrain feature, it should be emphasized that compared with this he has relatively little knowledge of his train's behavior when the large numbers of simultaneous dynamic and sequential events occurring on a moment-by-moment basis are considered. The behavior of the train is determined, for example, by drawbar forces, gross weight, weight distribution, lateral forces, long car/short car combinations, dynamically unstable cars, special equipment and even ambient temperature as it affects brake-pipe leakage.

The engineer must monitor the locomotive and train status and adjust his control inputs accordingly when maneuvering around curves, through switches, and over undulating and mountainous terrain, often under adverse weather conditions. Careful planning is necessary to insure that rolling stock and lading maintain their integrity to destination, prevent break-in-two and avoid derailment. Planning ahead and the resultant decision-making process is necessary because of the lead and lag characteristics of the control inputs and associated delayed feedback.

The stopping distance of the train, for example, under normal conditions may be several miles in front of the geographical point where the first input is made, and the deceleration does not take place at a constant rate. The rate is determined primarily by the train's speed. On the other hand, the serial action of a brake-pipe pressure reduction means that the release time at the last car of a long train may occur half a minute after the initial control input by the engineer.

It is also recognized that line-haul freight trains typically constitute a large capital investment by both the operating properties and shippers.

It is concluded, therefore, that the role of the train crew in freight operations may be characterized as complex and entailing a high level of responsibility.

Finally, the operating environment, i.e., the "right of way", can be hostile, with attendant anxieties due to the many risks. Crews have been killed by accident in locomotive cabs. The cab crew must be ever alert when monitoring locomotive-systems status, train status where possible, track condition, right of way, passing rolling stock, grade crossings, signals and train orders, to name just a few. In addition to all of the above, locomotive freight engineers may work up to 12 hours a day under a variety of weather conditions and on irregular shifts. Therefore, it is not difficult to appreciate the crew's need for a professional workspace and habitable cab.

A complex environment, such as the one just described, requires an effective man/machine interface to successfully accomplish the objectives of safe and efficient trainsporting of cargo. This contract will provide a design for an optimized working and living environment, including by applying human factors, occupant protection, and crashworthiness criteria.

The body of this report is presented in two sections. Section 2.0 contains the system functional analysis and Section 3.0 the detailed engineering analysis.

2. SYSTEM ANALYSIS

2.1 INTRODUCTION

This section presents a description of the methods used and results obtained during the system analysis. It is well known that in practice during preliminary design phases not every process as described in handbooks and specifications receives equal emphasis during the analytic stage. This is true because designs vary greatly in complexity, mission requirements, and amount of prior analytic effort. In some instances, for example, a proposed design effort may require incorporation of incremental technological advances in state-of-the-art engineering techniques; in other giant extrapolations into the unknown may be attempted. For these reasons judgement must be exercised in selecting areas for emphasis during preliminary design development. Accordingly, and as befitting the design development of a locomotive cab, the present systems analysis was performed in two successive steps: analysis of line-haul functional requirements, and analysis of the engineer's tasks. These are discussed in the following sections.

2.2 CAB DESIGNS, TECHNICAL DATA AND OPERATING PROCEDURES

The principal source of design and technical background data was the Electromotive Division of General Motors (EMD), functioning as a principal subcontractor during the study. Its input was supplemented by a review of the literature on cabs and cab design, and visits to the Southern Pacific and Penn Central Railroads. Figure 2-1 shows how these data were organized to provide a systematic categorization of cab functions gleaned from our understanding of present locomotive requirements. It was recognized early that for additional insight it would be important to understand in detail the dynamics of train operation in addition to principles and practices of cab design. Therefore, concurrent with analysis of the technical data, the study team reviewed operations, practices and procedures now employed. Sources such as the Track Train Dynamics Guidelines of the Government/Industry Research Program on train dynamics, railroad rulebooks, and timetables were reviewed. There were consultations with several experienced railroad officers and employees who agreed to participate. EMD provided data, information and perspective based on their experience. The study team consulted with local General Electric representatives on an occasional informal basis.

Functional requirements were determined by reviewing designs and technical data for representative operational cabs. Today, there are two manufacturers of cabs in the United States: EMD and General Electric. Each provides a basic cab configuration for each locomotive type that it makes.

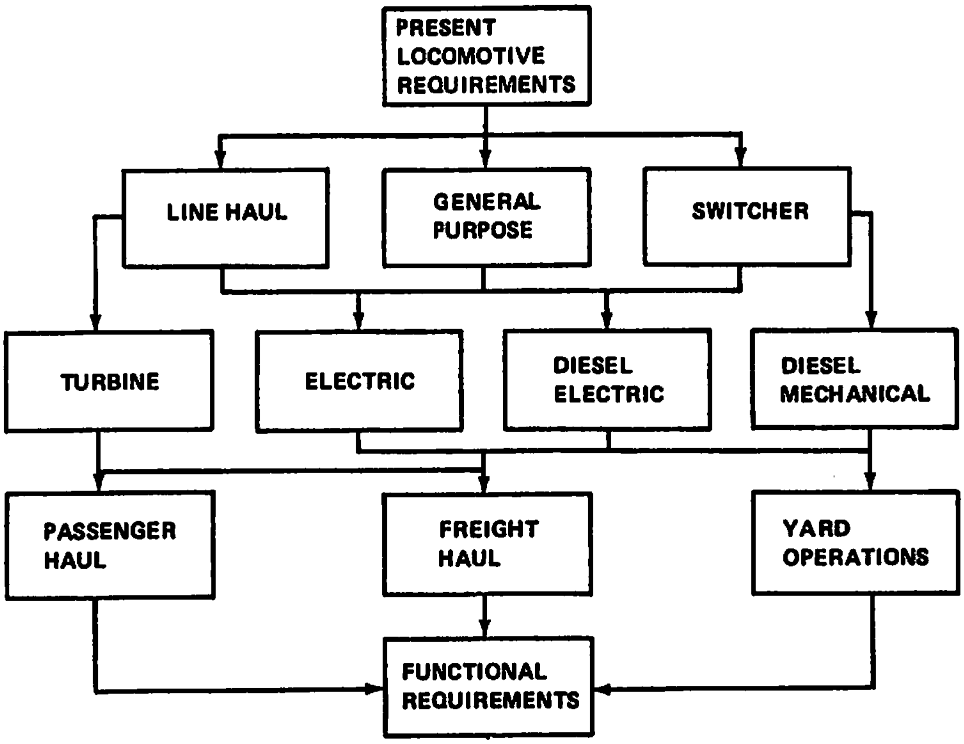


Figure 2–1. Locomotive Cab Requirements

The buyers may then select from a variety of options and those items which best suit their railroad's needs. Locomotives fall primarily into three categories: line-haul, general-purpose and yard-switcher. Line-haul and general-purpose may be either electric or diesel/electric, while switchers are usually diesel/electric with powered diesel/mechanical units employed in some industrial operations. Typically, the newer and higher-horsepower locomotives are used mainly for long journeys, and are operated primarily in one direction. General-purpose locomotives are also used for long-distance line haul, but they are more frequently used on short-haul road-switching missions with considerable reverse movement. Yard switchers, for example, are confined, as their name implies, to yard work such as forming consists, etc. Locomotives are often demoted as they get older, from line-haul to road switching. Many lower-horsepower locomotives may often be found performing switching and humping duties in large marshaling yards. As might be expected, cab layouts differ depending upon the locomotive function. Some cabs are designed primarily for forward locomotion. When the engineer in this type of cab wishes to move his locomotive in a reverse direction, he must either look out of his window back along the train in the direction of movement, or rotate his chair about 90° to obtain the same view through the cab rear-door window. The recently adopted standard AAR control stand is rotated 45° from crew centerline to accommodate this dual requirement. However, the line-haul locomotive spends by far the longest part of its time proceeding in a forward direction. Road switchers, on the other hand, may spend as much time in reserve as in forward movement as they cut cars in and out of sidings along the right-of-way, as do yard switchers when moving and forming cars and consists.

Another significant feature is the location of the cab on the locomotive. Locomotives today may be observed running with either the long hood or the short hood forward. The hood may be high or low depending on the desire of the property using it. In other instances, the locomotive may have a cab at either end, or as in some of the older models, the cab may be located intermediately along the locomotive.

It is clear that visibility from these cabs does vary significantly. It is dictated primarily by two considerations: first, the cab is accommodated to the arrangement of the power plant and propulsion systems; and second, there is a distinct advantage from the standpoints of crashworthiness and occupant protection to position the cab as far back from the front as practical. At least one railroad requires locomotive manufacturers to install the cab so normal line-haul operations take place with the long hood forward. Nowhere, however, was the study team able to locate any source or data that would indicate that visibility, consequent windscreen location, or design was based on formal analysis of the engineer's vision requirements. It was concluded, however, that in spite of the wide variety of cabs and their diversity of use, significant engineman functions were the same: namely, maneuvering and controlling the train. The line-haul operation was found, after review, to be not only the most complex set of functional requirements, but also the most complete set in that it incorporates all requirements appearing to some degree in road switching and yard switching.

The next question addressed was the operational use of locomotives either individually, in a locomotive consist, or as a helper unit. Line-haul operations were reviewed and procedures studied to identify functions necessary to accomplish over-the-road missions, and to identify tasks that the engineer and crew perform to meet requirements. A literature review was made and a bibliography is appended to this report. Included are relevant reports from the Government/Industry Research Program on track dynamics, handbooks, representative routes, timetables, operating manuals, rule books, communication procedures, signal aspects, regional variations in train handling, federal regulations, encyclopedias, trade journals, union and management periodicals, and reports of accidents where there was injury or death to personnel. Visits were made to the Southern Pacific Railroad's training simulator at Cerritos, California, and the Penn Central facilities at 30th Street Station in Philadelphia, the Wilmington maintenance depot, and the Enola yards. The team rode in the cab of an E-44 which was hauling 67 freight cars of produce from Enola to Baltimore. Members of the study team visited EMD and drove an SD-45 equipped with dynamic braking on their test track. The team also rode in an EMD SW-1500 during yard-switching operations.

As a result of these visits ample opportunity was provided to talk with operating personnel representing both the union and management points of view.

It should be emphasized, however, that considerable effort has been expended over the years to provide the locomotive engineer with a safe working environment. The railroad brotherhoods, AAR, FRA, manufacturers, and the properties themselves have sponsored activities to improve working conditions, train handling and particularly occupant protection. Recent studies by the Clean Cab Committee, for example, have resulted in a set of recommendations which are now being adopted by many railroads for improving locomotive cabs. Nevertheless, the development of locomotive cabs has been and still is an evolutionary process. This is true because cab designs are rooted in history. Some steam-locomotive influences are still present in today's cabs. It is apparent the locomotive cab must satisfy a diversity of work task requirements, and must be acceptable to the crew as a safe working and living area.

The present cab design results from a different "clean sheet of paper" approach based on a modern list of functional requirements. Its purpose is to optimize the cab work station and general layout. A detailed human-factors systems-engineering analysis was performed based on the study of cab designs, technical data, railway operating procedures, and other pertinent data. This analysis served as a first step in defining the design options available, and subsequently facilitating the choice of a functional baseline cab for design development. The approach has been used successfully many times in military, aerospace and commercial systems. It provides a tool for systematically defining the equipment, personnel, facilities and procedures used in line-haul freight operations.

2.3 FUNCTION ANALYSIS

Figure 2-2 shows how the operational requirements were translated into tasks for further analysis and development. These tasks were analyzed in increasing depth of detail from general to the very specific in the manner described in the following paragraphs. These requirements were developed to provide inputs for the information and actions discussed in a later passage. Subsequent steps entailed the functional analysis by locomotive system and subsystem leading to our recommended design.

2.3.1 First-Level Functions

The first-level functions represent the synthesis of our operational and design reviews. Although, as stated in the preceeding paragraphs, a wide variety of uses for locomotives and cab designs was encountered, some general principles could be extracted. Based on the initial review, we concluded that these principles represented the most complex set of functional requirements, and therefore constituted the severest test of a locomotive cab design. The functional requirements are:

a. Multiple-Unit Operation
b. Helper Consists
c. Range of Speeds
d. Variety of Track Conditions
e. Diverse Environments
f. Mix of Loads and Cars
g. Day/Night Operations
h. Flat/Rolling/Mountainous Terrains
i. Bi-Directional Movement
j. Communications
k. Operational Safety and Reliability

Multiple-unit operation is a routine operation on most class 1 railroads, where multiple unit is defined as more than one locomotive in a locomotive consist.

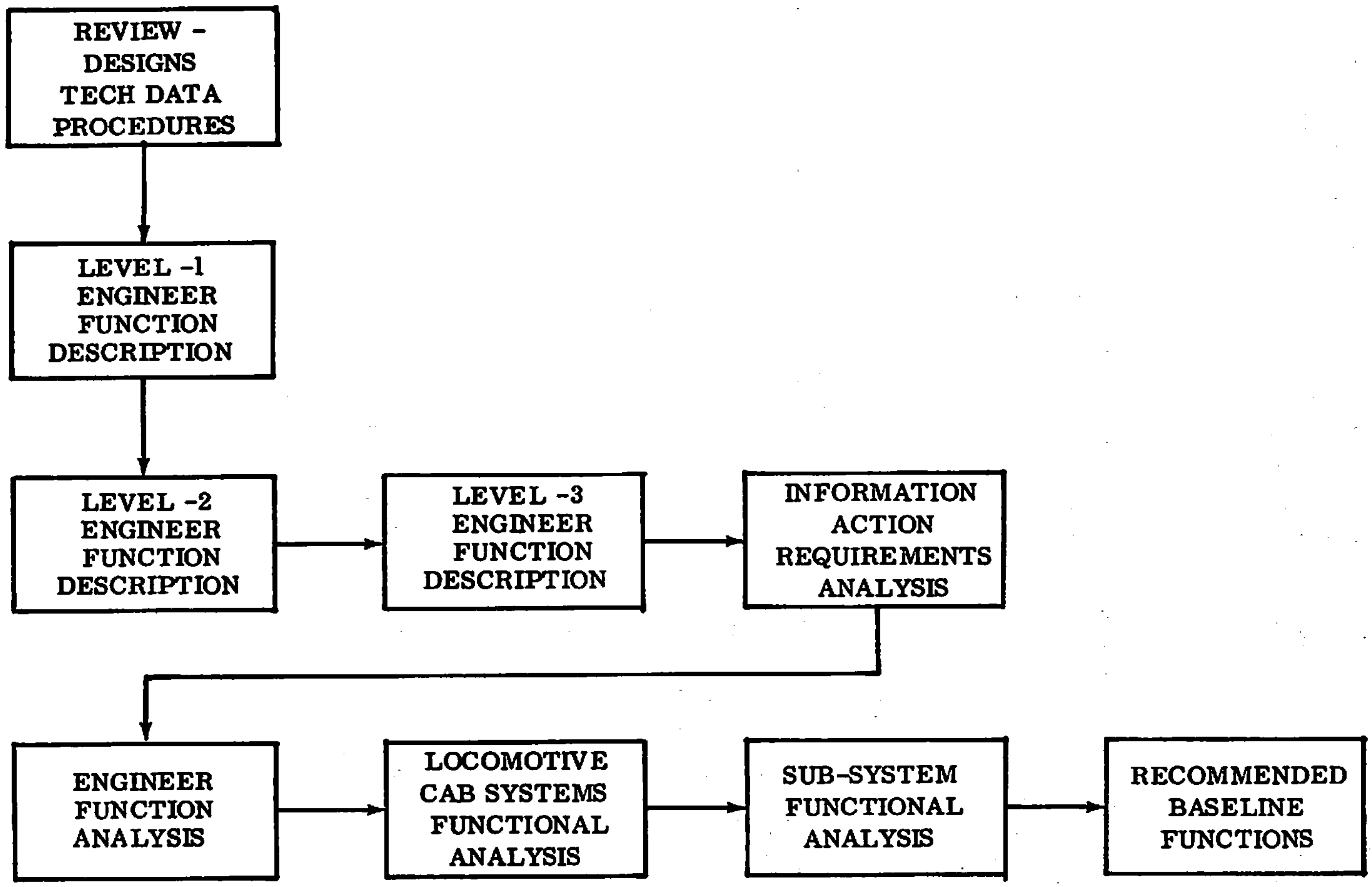


Figure 2–2. Baseline Cab Functional Analysis

Helper consists are often employed on extremely long trains, particularly where steep grades are to be encountered. It is important to note that these helper consists may be either directly controlled by enginemen stationed in the helper units, directly controlled through radio communications, or remotely controlled by means of a data link.

Of special significance to the design of a new cab is that it must be operable over a variety of track conditions, in diverse environments and over diverse terrains with a mix of cars (age and loads), and perform day and night operations with equal efficiency. Our analysis has also revealed that modern cabs must be capable of bidirectional movement with equal facility, as this mode of utilization is routinely employed by the operating railroads. This is a significant feature that was carefully considered in detail during the design phase of the study because present designs pose considerable inconvenience to the engineer. Last but not least, the locomotive cab must provide for safe and reliable operations in conjunction with adequate and intelligible communications among the train crew and wayside personnel.

2.3.2 Second-Level Train Functions

Second-level functions, the next level of system indenture, are presented in Figure 2-3. The functions were constructed to show the activities and options available to or required by the crew to meet the requirements defined at the first level. The breakout at this level is to be construed, not as a rigid operational sequence, but rather as a systematic framework for delineating tasks in greater detail.

2.3.3 Third-Level Functions

Based on the above functions, block diagrams were prepared for each element in the composite. These diagrammatic presentations are top-down, that is, beginning with the most general functions, and ending with specific tasks. The functions identified in this way are systems-oriented and non-specific. They define functional characteristics and operations without distinguishing the particular detailed human/hardware aspect of the function.

The function blocks under each heading represent the tasks needed to perform the parent function, as shown in Figure 2-4. The primary purpose of this level of the analysis is to serve as inputs to the information/action requirements leading to a systematic listing of control and display requirements as well as the tasks associated with them.

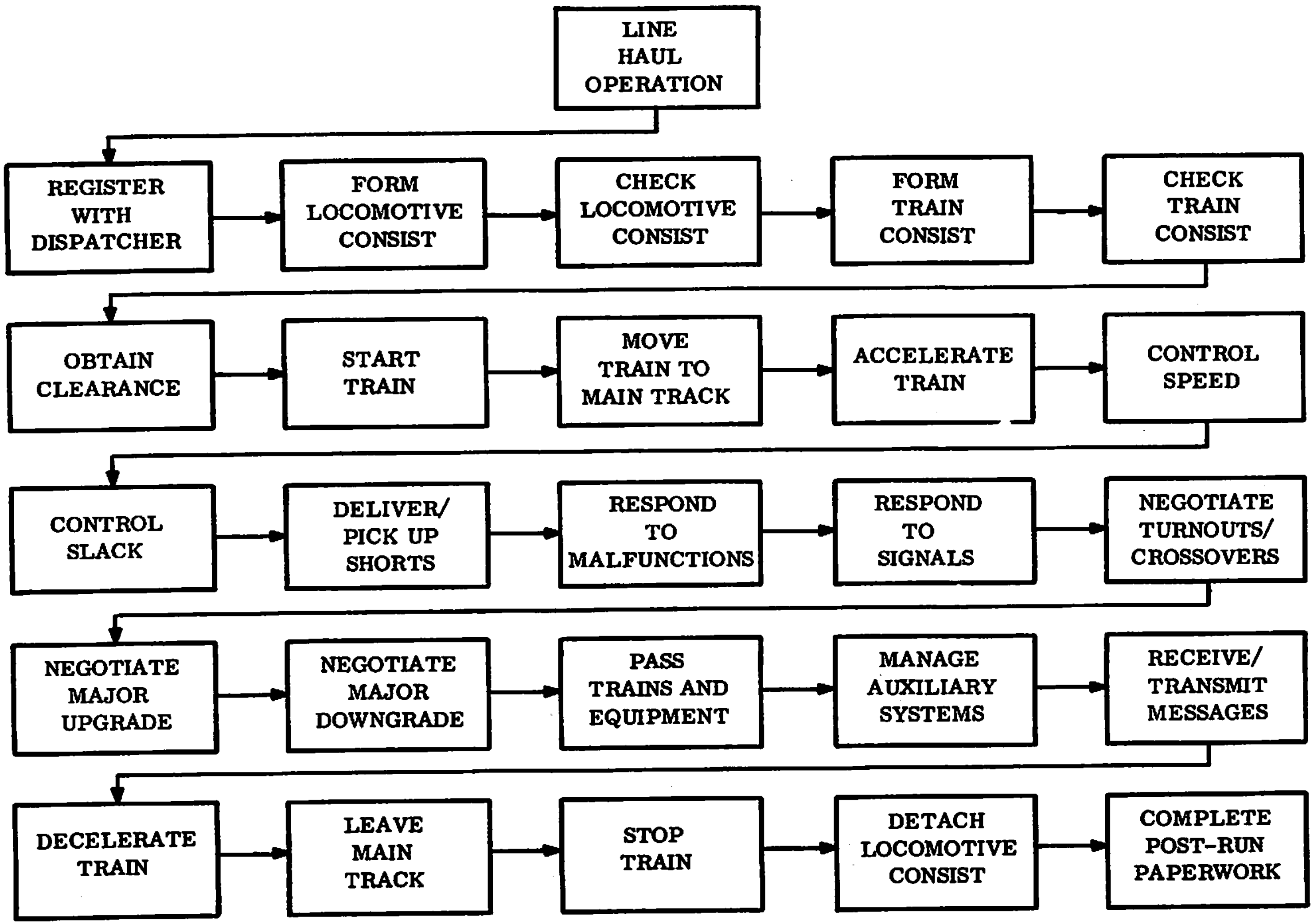


Figure 2–3. Second-Level Train Functions

Each function, it may be noted, has some implication for cab design. For example, when Figure 2-4 is examined, we note that after registering with the train dispatcher, the engineer and conductor perform the necessary steps to brief themselves on the day's assignment. This mission briefing includes type of trip, applicable rules, type of train, train make-up schedule, and special orders. It is implicit that this information is taken along by the crew either in their heads, or in a written form, such as train orders. Provision must be made during design to provide this information as they need it (mission-oriented requirement), and to stow it properly for later retrieval (habitability-oriented requirement). This approach of noting the implicit and explicit content of the functions was taken throughout the analysis, and an additional example may suffice. Figure 2-5 shows that under the heading "start train", train information must be reviewed prior to taking any action to move the train. Each functional response requires its own individual analysis and associated decision: whether to implement it manually with hardware, or with computational software. (The complete analysis is presented in Appendix A.) Many of the tasks identified at level three appear repetitively. Therefore, after ascertaining that all significant engineer functions were accounted for, we summarized them as follows:

1. Propulsion System

    Apply/Release Tractive Effort
    Activate Generator Field
    Set Direction of Travel
    Read Traction Motor Temperature
    Read Tractive Effort
    Read Power-Force

2. Train Brake System

    Apply/Release Train Brakes
    Read Brake Pipe Pressure
    Read Equalizer Pressure
    Read Brake Pipe Pressure Gradient
    Read Brake Pipe Flow
    Hear Pressure Venting

3. Locomotive Brake System

    Apply/Release Locomotive Brake
    Hear Pressure Venting
    Read Brake Cylinder Pressure

4. Pneumatic System

    Read Main Reservoir Pressure

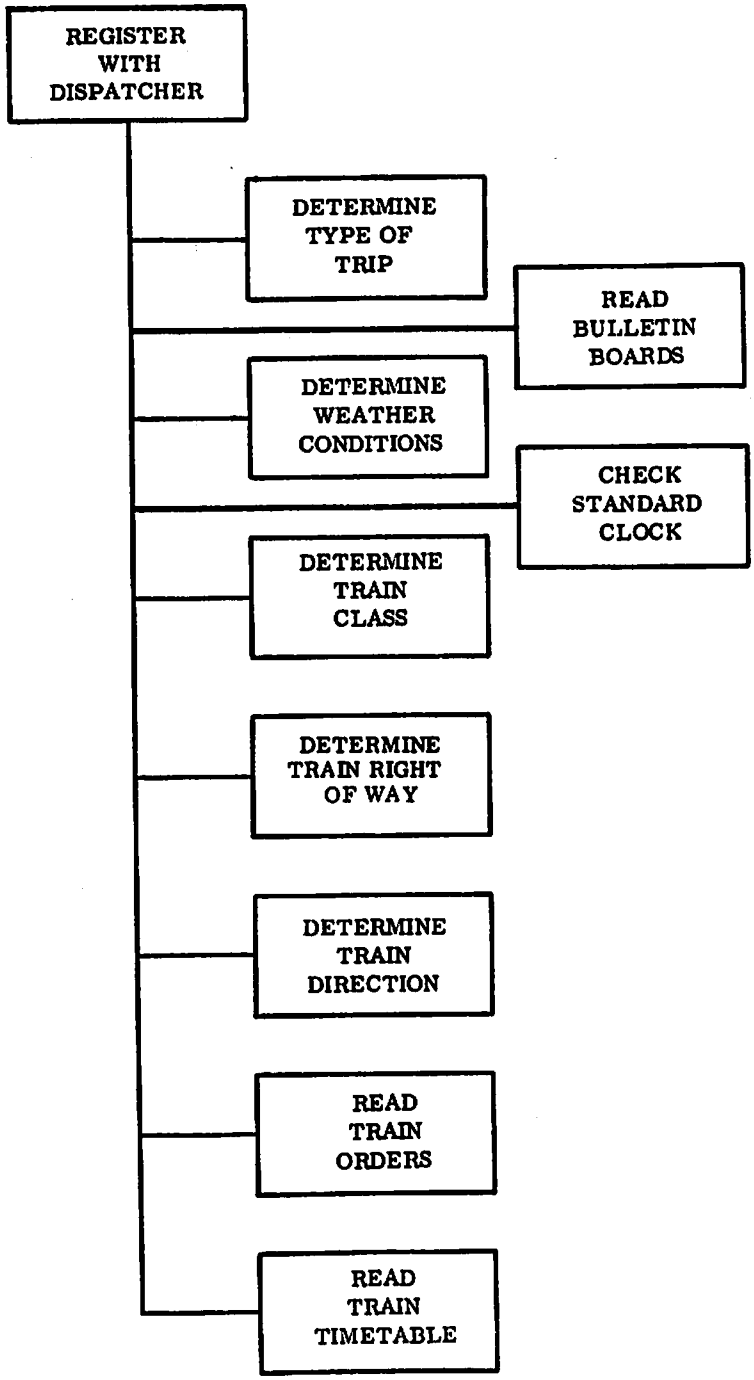


Figure 2–4. Typical Level 3 Crew Functions

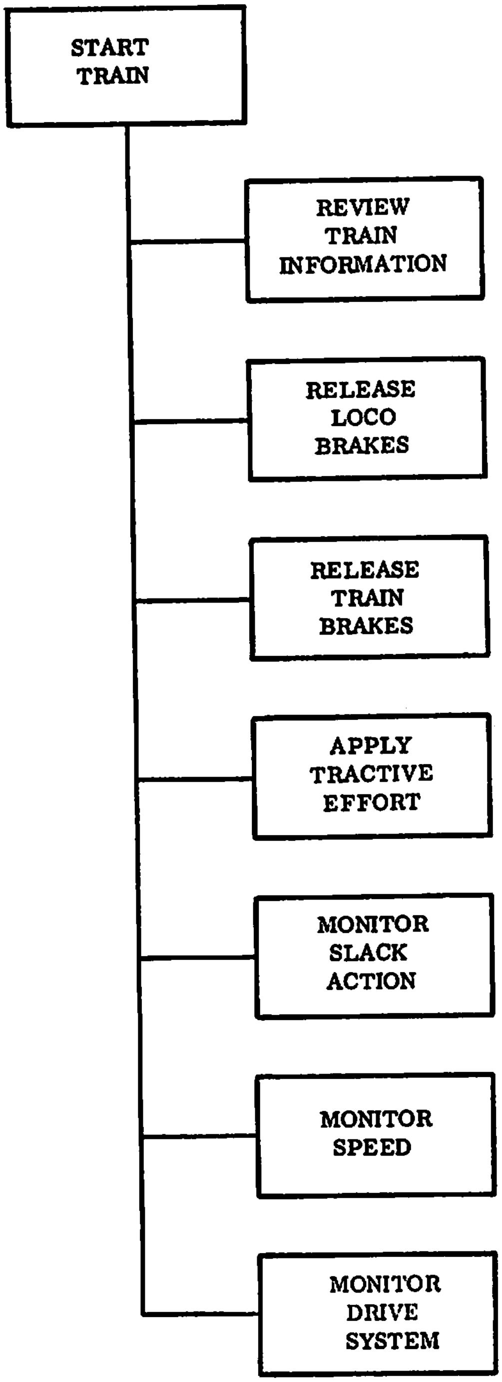


Figure 2–5. Typical Level 3 Crew Functions (Continued)

5. Dynamic Brake System

   Apply/Release Dynamic Brake
   Reset Dynamic Brake Circuit Breaker
   Set Dynamic Brake Cutout
   Read Dynamic Brake Meter

6. Drive System

   Read Speed
   Monitor Speed Rate of Change
   Read Wheel Slip/Slide
   Apply Sand
   Read Automatic Sanding
   Monitor Malfunctions

7. Engine System

   Read Low Oil
   Read Hot Engine
   Read No Power
   Hear Alarm Bell
   Hear RPM Change

8. Train/Train Situation

   Read Grade
   Read Curvature
   Read Train Slack
   Read Drawbar Force

9. Signals

   Read Cab Signals
   Read Ground Signals
   Read Hand Signals

10. External Environment

    Monitor Track Condition/Obstructions
    Monitor Parallel Tracks
    Perform Rollby Inspection
    Monitor Own Train

11. Auxiliary Systems

Manage Warning Devices
Manage/Monitor Communication System
Manage Exterior Lights
Manage Interior Lights
Manage Heating, Ventilation, Air Conditioning
Manage Windshield Condition

2.3.4 Subsystem Analysis

The final list of functions was correlated to real cab designs by constructing a matrix of events, as shown in Figure 2-6. Level-two functions are presented along the ordinate and level-three functions along the abscissa by locomotive subsystem. A dot was entered in the matrix wherever a subsystem activity was performed to meet a mission requirement. This format was selected to provide a preliminary objective assessment of the relative importance of each function to the total line-haul mission. This was done by counting the dot entries in the matrix by rows (mission events) and columns (subsystem functional requirements) and then rank-ordering them.

Table 2-1 showsthe rank order of importance for mission requirements summed over the subsystem tasks. As was to be expected, train maneuvering functions constituted the bulk of the most frequent activities. It should be noted that this format indicates task frequency and should not be interpreted as a work-load analysis. The rationale for ordering functions in this way is to provide a preliminary guide to the location and general layout of controls and displays in terms of their frequency of use.

The next breakout is shown in Table 2-2. Here matrix entries were totaled for each locomotive subsystem. The subsystem totals were also ranked. It is interesting to note that the automatic braking system occupies a significant portion of the engineman's activities, and again this was not entirely unexpected. Surprisingly, however, the drive system was rated number two ahead of viewing and responding to the external environment. This finding seemingly ran counter to observations of the engineers' performance during actual over-the-road line haul operations. Examination of the matrix entries for this subsystem revealed however that the drive system, which has been defined as the traction motor gears, drive wheels, axles, bearings, and speedometer, obtained its number-two status primarily due to the requirement to continuously monitor and maintain speed. Similarly, although this was not obvious to the observer, auxiliary systems earned the rank of number-six position because carrier operating rules require extensive use of the horn.

ENGINEMAN FUNCTION LIST / LEVEL 2 FUNCTIONS	PROPULSION SYSTEM						TRAIN BRAKE SYS						LOCO BRAKE SYS			PNEUMATIC SYS
	Apply/rel tractive effort	Activate generator field	Set direction of travel	Read traction motor temp	Read tractive effort	Read power-force	Apply/rel train brakes	Read brake pipe press	Read equalizer press	Read B. P. press gradient	Read B. P. flow	Hear press venting	Apply/rel loco brake	Hear press vent	Read brake cyl press	Read main reservoir press
Register with dispatcher																
Form loco consist	•	•	•										•	•	•	•
Check loco consist					•	•							•	•	•	•
Form train consist	•		•				•	•	•	•	•	•	•	•	•	
Check train consist							•	•	•	•	•	•				•
Obtain clearance																
Start train	•	•	•	•	•	•	•	•			•		•	•	•	
Move train to main track	•				•	•		•			•	•	•	•	•	•
Accelerate train	•			•	•	•										
Control speed	•				•	•	•	•	•	•	•	•	•	•	•	•
Control slack	•				•	•	•	•	•	•	•	•	•	•	•	•
Deliver/pick up shorts	•		•		•	•	•	•	•	•	•	•	•	•	•	•
Respond to malfunctions	•						•	•	•	•	•	•	•	•	•	•
Respond to signals	•						•	•	•	•	•	•				•
Negotiate turnouts/crossovers	•						•	•	•	•	•	•	•	•	•	•
Negotiate major upgrade	•			•	•	•										
Negotiate major downgrade							•	•	•	•	•	•				•
Pass trains and equipment																
Manage aux. sys																
Receive/transmit messages																
Decelerate train	•						•	•	•	•	•	•	•	•	•	•
Leave main track	•				•	•	•	•	•	•	•	•				•
Stop train	•						•	•	•	•	•	•	•	•	•	•
Detach loco consist	•	•	•										•	•	•	•
Complete paper work																

ENGINEMAN FUNCTION LIST / LEVEL 2 FUNCTIONS	DYNAMIC BRAKE				DRIVE SYSTEM						ENGINE SYSTEM					TRACK TRAIN SITUATION			
	Apply/rel dynamic brake	Reset D. B. ctl. brkr	Set D. B. extend	Read D. B. meter	Read speed	Mon. speed rate of change	Read wheel slip/slide	Apply sand	Read auto sand	Mon. malfunctions	Read low oil	Read hot engine	Read no power	Hear alarm bell	Hear rpm change	Read grade	Read curvature	Read train slack	Read drawbar force
Register with dispatcher																			
Form loco consist		•	•		•														
Check loco consist	•			•	•					•	•	•	•	•	•				
Form train consist					•														
Check train consist										•									
Obtain clearance																			
Start train					•	•	•	•	•						•	•	•	•	•
Move train to main track	•			•	•	•									•		•	•	
Accelerate train					•	•	•	•	•						•	•	•	•	•
Control speed	•			•	•	•									•	•	•	•	•
Control slack	•			•	•	•										•	•	•	
Deliver/pick up shorts					•		•	•	•						•				
Respond to malfunctions		•			•						•	•	•	•	•	•	•	•	
Respond to signals	•			•	•														
Negotiate turnouts/crossovers	•			•	•		•		•										
Negotiate major upgrade					•	•	•	•	•							•	•	•	•
Negotiate major downgrade	•			•	•	•	•	•	•							•	•	•	•
Pass trains and equipment																			
Manage aux. sys																			
Receive/transmit messages																			
Decelerate train	•			•	•	•	•	•	•						•	•	•	•	•
Leave main track					•	•									•	•	•	•	
Stop train					•	•	•	•	•							•	•	•	•
Detach loco consist																			
Complete paper work										•	•	•	•	•					

ENGINEMAN FUNCTION LIST / LEVEL 2 FUNCTIONS	SIGNALS			EXTERNAL ENVIRON.				AUXILIARY SYSTEM					
	Read cab signals	Read ground signals	Read hand signals	Mon. track cond./obstruct	Mon. parallel tracks	Perform roll'by inspection	Mon. own train	Manage warning devices	Manage mon. commo sys	Manage ext. lights	Manage int. lights	Manage HVAC	Manage windshield cond.
Register with dispatcher													
Form loco consist			•	•	•		•	•		•	•	•	•
Check loco consist	•							•		•			
Form train consist			•	•	•		•	•	•				
Check train consist	•	•		•	•		•		•				
Obtain clearance	•	•		•	•		•		•				
Start train	•	•	•	•	•		•	•	•	•			
Move train to main track	•	•	•	•	•		•	•	•	•			
Accelerate train	•	•		•	•		•						
Control speed	•	•		•	•		•		•				
Control slack				•	•		•		•				
Deliver/pick up shorts		•	•						•				
Respond to malfunctions				•			•						
Respond to signals	•	•	•	•			•	•	•	•			
Negotiate turnouts/crossovers	•	•	•	•	•		•	•	•	•			
Negotiate major upgrade	•	•			•		•						
Negotiate major downgrade	•	•			•		•						
Pass trains and equipment			•		•	•	•	•	•	•	•		
Manage aux. sys								•	•				
Receive/transmit messages		•	•					•	•		•		
Decelerate train	•	•			•		•						
Leave main track	•	•	•		•		•	•	•	•			
Stop train	•	•	•		•		•	•	•	•	•		
Detach loco consist					•		•		•		•		
Complete paper work													

Figure 2-6. Engineer Functional/System Variable Matrix

TABLE 2-1. ORDERED MISSION REQUIREMENTS

Rank Order		Matrix Entries
1.	Start Train	(31)
2.	Stop Train	(29)
3.	Control Speed	(28)
4.	Decelerate Train	(27)
5.5	Negotiate Turnouts and Crossovers	(26)
5.5	Move Train to Main Track	(26)
7.5	Leave Main Track	(24)
9.	Respond to Malfunctions	(23)
10.5	Negotiate Major Downgrade	(22)
10.5	Deliver/Pick Up Shorts	(22)
12.5	Accelerate Train	(19)
12.5	Respond to Signals	(19)
15.	Form Train Consist	(18)
15.	Form Locomotive Consist	(18)
15.	Check Locomotive Consists	(18)
17.	Negotiate Major Upgrade	(17)
18.	Check Train Consist	(14)
19.	Detach Locomotive Consist	(11)
20.	Pass Trains and Equipment	(8)
21.	Obtain Clearance	(6)
22.	Receive and Transmit Messages	(5)
23.	Manage Auxiliary Systems	(2)

TABLE 2-2. LOCOMOTIVE SUBSYSTEM/ENGINEER TASK FREQUENCIES

Rank Order	Subsystem	Matrix Entries
1.	Train Brake System	(77)
2.	Drive System	(52)
3.	Exterior Environment	(50)
4.	Propulsion System	(45)
5.	Locomotive Brake System	(39)
	Track/Train Situation	(39)
	Signals	(39)
6.	Auxiliary Systems	(31)
7.	Engine System	(22)
8.	Dynamic Brake	(19)
9.	Pneumatic System	(15)

It should be emphasized again that this format provided initial guidelines for implementing these functions during the preliminary locomotive-cab-design phase. Crew-station design specifications (MIL-STD-1472A, for example) specify control and display envelopes to optimize crew performance. Thus, the method employed provides an objective, but admittedly a somewhat arbitrary basis for preliminary cab layout to conform both to operational requirements and good human-engineering design standards and practices.

Continuing the analysis in the same vein, we ranked the functions identified within each subsystem, using the referenced matrix entries as shown in Table 2-3. For example, functional requirements suggest that under the train brake system, all items deserve equal consideration during the design of controls and displays to implement these requirements. It is also true that in the consideration of monitoring and adjustment tasks, the propulsion system that throttles adjustment is extremly important when compared, for example, to knowing the traction motor temperature.

The rationale used here is the same as the one presented in the previous section. That is, just as the overall layout within the cab work station is significant, the details of arrangement within each subsystem (the most natural grouping of controls and displays for a given task) must be considered.

2.4 INFORMATION/ACTION REQUIREMENTS

To bridge the gap between the functional analysis done in the abstract and the detailed human-engineering design, an information and action requirements analysis was performed. The analysis included stimuli present, decisions required and actions performed by the cab crew. As stated in the introduction, it was recognized that the engineer's behavior was not just a matter of preplanned on-off stimulus-response relationships, but rather revealed significant adaptive lead and lag components. The engineer needed these to plan his train handling. The complete analysis is presented in Appendix B.

Examination of Figure 2-7, a typical example, shows that in the extreme left column are listed the functions identified at the previous level of indenture. The background information actions and feedback needed to accomplish each function are listed in the appropriate columns to the right. These columns spell out the control and display functional requirements of the locomotive engineer in today's environment. Under the "Information" heading are shown the types and sources of information (stimulus inputs) that the engineer requires to accomplish each function, from his locomotive (or locomotive consist) train and the external environment. Under the "Action" heading, the action refers to the engineer's response as required.

TABLE 2-3. LOCOMOTIVE SUBSYSTEM FUNCTION ANALYSIS

Rank Order		Matrix Entries
	Train Brake Subsystem	
1.5	Monitor Brake Pipe Pressure	(14)
1.5	Monitor Brake Pipe Flow	(14)
3.5	Apply/Modify Train Brakes	(13)
3.5	Monitor Pressure Venting	(13)
5.5	Monitor Equalizer Reservoir Pressure	(12)
5.5	Monitor Brake Pipe Pressure Gradient	(12)
	Propulsion Subsystem	
1.	Apply/Release Tractive Effort	(16)
2.5	Read Tractive Effort	(9)
2.5	Read Power-Force	(9)
4.	Set Direction of Travel	(5)
5.5	Activate Generator Field	(3)
5.5	Read Traction Motor Temperature	(3)
	Dynamic Brake Subsystem	
1.5	Apply/Release Brake	(8)
1.5	Read Brake Meter	(8)
3	Reset Dynamic Brake Circuit Breaker	(2)
4	Set Dynamic Brake Cutout	(1)
	Locomotive Brake System Subsystem	
-	Apply/Release Brake	(13)
-	Read Brake Cylinder Pressure	(13)
-	Hear Pressure Venting	(13)
	Pneumatic Subsystem	
-	Read Main Reservoir Pressure	(15)
	External Environment	
1	Monitor Own Train	(19)
2	Monitor Parallel Tracks for Oncoming Trains	(17)
3	Monitor Track Condition/Obstructions	(12)
4	Perform Rollby Inspection	(1)

TABLE 2-3. LOCOMOTIVE SUBSYSTEM FUNCTION ANALYSIS (Continued)

Rank Order		Matrix Entries
	Drive Subsystem	
1	Read Speed	(17)
2	Monitor Speed Rate of Change	(10)
3.5	Read Auto Sand	(8)
3.5	Read Wheel Slip	(8)
5	Apply Sand	(7)
6	Monitor Drive System	(3)
	Track Train Situation	
1.5	Read Curvature	(11)
1.5	Read Slack Condition	(11)
3	Read Grade	(10)
4	Read Drawbar Force	(7)
	Signals Subsystem	
1	Read Wayside Signals	(15)
2	Read Cab Signals	(14)
3	Read Hand Signals	(11)
	Auxiliary Subsystem	
1	Manage/Monitor Communications Systems	(16)
2	Manage Warning Devices	(12)
3	Manage Exterior Lights	(9)
4	Manage Interior Lights	(5)
5.5	Manage Heating, Ventilation and Air Conditioning	(1)
5.5	Manage Windshield Controls	(1)
	Engine Subsystem	
1	Hear Engine RPM Change	(9)
3.5	Read Low Oil	(3)
3.5	Read Hot Engine	(3)
3.5	Read No Power	(3)
3.5	Hear Alarm Bell	(3)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
INITIATE TRAIN MOVEMENT	Train mass distribution	Train mass dist. graph	Apply tractive effort	Throttle	Throttle posn.	Throttle pos. ind.
	Loco consist characteristics	Briefing			Speed	Speedometer
					Traction motor load	Loadmeter
	Type brake equipment	Inspection				
	Slack condition	Slack ind.			Slack action	Slack ind.
	Number of cars	No. cars ind.	Modify tractive effort	Throttle	Throttle position	Throttle pos. ind.
	Special loads	Special load ind.			Speed	Speedometer
	Grade/curvature	Grade/curve ind.			Traction motor load	Loadmeter
	Weather	Briefing				
	Direction of movement	Reverser			Slack action	Slack ind.
					Commo with caboose	Radio
	Clearance	Dispatcher				
			Apply sand	Sand control	Wheel slip/slide	Wheel slip indicator
					Sanding	Sanding ind.
			Read Power-Force	Power-Force Ind.	Drawbar force	Drawbar force ind.

Figure 2–7. Typical Information and Action Requirements Analysis

Finally, the column called "Feedback" presents confirmation that operating requirements have been met and the information may in turn serve as future stimuli for planned activities. The purpose of this phase of the analysis is to integrate the previous steps of the functional analysis into a framework that will then produce a comprehensive set of concrete tasks performed by the engineman. These tasks are, as specified above, in the form of the information gathering needed to perform a function (actions made as a result of the information, and feedback on those actions). With this format, the analyst has a tool that enables him to examine the initiation and feedback loop processes that are present in the cab environment. Once these processes were understood, the "source" columns under each category yielded the preliminary control or display feature necessary to accomplish each step in the train-handling process.

The source columns on the information/action requirements work sheets were reviewed to determine display/control requirements and treated in the following manner.

2.4.1 Displays

Candidate displays were initially identified and some preliminary criteria established. As shown in Table 2-4 for example, scale values (quantitative or qualitative), and type of presentation were evaluated. An X entered in the table indicates the requirement to be met, while an A indicates that the information was a candidate for a discrete or annunciator presentation. Next the candidates were laid out in a more detailed matrix as shown in Table 2-5, and a trade was performed in the following manner. Taking the first row as an example, we note that the candidate is Traction Motor Load. Reading across the columns shows that amperes in the display unit with a total range of 0-1500 amps, attainable by the locomotive with an operating limit of 0-1070 amps which as noted in the next column would be indicated by a red range limit indication. Increments, as presently displayed, in locomotive cabs are in 20-amp steps. Reading onto the next column, we note that trend information is required as an indication of increasing or decreasing torque development. Accuracy is not necessary from an engineering-operations standpoint, but does have some utility for maintenance and check-out.

Finally, rate of change is a significant parameter along with the trend information in the previous column. The next six columns contain the preliminary design-alternative display types. For the traction motor load a round dial instrument was selected as best satisfying the criteria. It should be noted that a vertical tape presentation was considered because of economy of space; however, it was rejected on the ground that it is difficult to display and interpret rate information with a tape within the operating limits of the parameter unless it is greatly expanded, defeating the space saving; or unless rate alone is displayed as a separate parameter on a dedicated rate indicator. This was judged to be a very complex human-factors engineering solution to a relatively simple problem.

Table 2–4. Preliminary Display Criteria

	Scale	Check Reading	Qual. Reading	Quant. Reading	Pointer Alignment	Remarks
Slack	S - B		X			
Draw. Bar.	0 - 300,000 lbs.			X		
Power/Force	0 - 300,000 lbs.			X		
Mass Dist.	0 - x tons		X	X		
Time	60 Min 60 Sec			X X		
Cab Signal	Color Code		X			
Over Speed	On-Off	X	X			A
Penalty Brk Appl.	On-Off	X	X			A
Oil Filter Clogged	On-Off	X				A
Fuel Filter Clogged	On-Off	X				A
PCS Open	On-Off	X				A
Excitation Limit Fail	On-Off	X				A

Table 2–4. Preliminary Display Criteria (continued)

	Scale	Check Reading	Qual. Reading	Quant. Reading	Pointer Alignment	Remarks
Eng. Over Temp	On-Off	X	X			A
Oil Level Low	On-Off	X	X			A
Water Level 10	On-Off	X	X			A
No Battery Charge	On-Off	X	X			A
Crankcase Over PR	On-Off	X	X			A
Blower Fail	On-Off	X	X			A
Air Filter Clogged	On-Off	X	X			A
Overload Rly Tri	On-Off	X	X			A
Turbo Air Lo Pres	On-Off	X	X			A
Fuel Press Lo	On-Off	X	X			A
Oil Press Lo	On-Off	X	X			A
Grade	0 - 3%		X	X		
Curvature	0 - 12°		X	X		

Table 2–4. Preliminary Display Criteria (continued)

	Scale	Check Reading	Qual. Reading	Quant. Reading	Pointer Alignment	Remarks
Traction Motor Over Temp	On-Off	X	X			A
Train Orders	Written			X		
Throttle Position	Idle, 1-8			X		
B.P. Gradient	20 PSI Spread		X			
B.P. Venting	On-Off		X			A
B.C. Venting	On-Off		X			Not Needed
Emerg. Brk Appl.	On-Off		X			A
Main Res. Low	On-Off	X	X			
Compress. Funct.	On-Off	X	X			A
Dyn. Brk. Pos.	Off, 1-8			X		
Wheel Slip	On-Off	X	X			A
Sanding	On-Off	X	X			A
Grd. Relay Trp.	On-Off	X	X			A

Table 2–4. Preliminary Display Criteria (continued)

	Scale	Check Reading	Qual. Reading	Quant. Reading	Pointer Alignment	Remarks
Main Res.	0–160	X	X			
B.P. Press	0–130			X	X	
B.P.P. Reduction				X		Not Needed (cumulative)
E.Q. Press	0–130			X	X	
Brk Cyl Press	0–120			X		
Traction Motor Load	0–1500		X			
Dynamic Brk Load	0–800		X			
Speed	0–100			X		
Speed Rate of Change			X			Not Needed
B.P. Air Flow	0–5	X	X			

2.4.2 Controls

The assessment of preliminary control was done the same way. Consider, for example, in the first row under controls "Throttle" in Table 2-6. Present applications show that the throttle has "stop", "idle" and eight throttle positions. It should be noted that some carrier applications call for a vernier setting which permits virtually continuous throttle adjustments within a selected throttle setting for firmer speed adjustments. Reading to the next column, note that the present control stand employs a lever with pointer and position indicator. The next two columns present advantages and control-stand space required. The remaining columns state the preliminary control type selected and preset alternatives.

It should be emphasized that these "work sheets" constitue the end of the formal systems analysis and in this sense must be viewed as preliminary.

In summary, based on the functional analysis and an understanding of the locomotive operative environment, the requirements for the initial design of each control and display could be detailed. The main headings chosen in conformance with standard HFE design practice to drive the design for the displays were units for the display, total display range, operating limits, display coding, incremental values, and whether the display was used to gather parameter trend information, accurate situation information, or rate-of-change information.

From this point, candidate instrumentation was reviewed (i.e., round dial, vertical tape, digital display, etc.) and a trade-off study performed. This trade-off study was based on the functional requirements of the engineman and criteria identified in the literature, tried and true human-engineering design standards, and the documented experience of human-factors engineers in aerospace and other applicable industries.

For each control the main points of interest were the necessary functional positions, and whether the action type was continuous or discrete. In both cases, an informal trade study was performed to determine appropriate display and control types. For example, a lever, rotary selector or handwheel was deemed more appropriate for a throttle than were other control types such as toggle switches or push buttons.

At this point, it was concluded that enough functional information had been generated to act as input to the detailed design of the locomotive cab.

Table 2–5. Display Requirements Analysis (Sheet 1 of 4)

CANDIDATE DISPLAY	UNITS	TOTAL RANGE	OPERATING LIMITS	CODING	INCREMENTS	TREND INFO	ACCURACY	RATE OF CHANGE	ALTERNATIVE DISPLAY TYPE: Printed Matter	Annun-ciator	Digital	Round Dial	Vert. Tape	Pictorial
Traction Motor Load	Amps	0-1500	0-1070	Red Line 1070	20 Amps	Yes	No	Yes	No	No	No	Yes	No	No
Traction Motor Temp	Degrees	TBD	TBD	Caution	Hi-normal	No	No	No	No	Yes	No	No	No	No
Train Orders	NA	NA	NA	NA	NA	No	Yes	NA	Yes	No	No	No	No	Yes
Throttle Position	NA	1-8	NA	NA	1	No	No	No	No	No	Yes	No	No	No
Brake Pipe Press	PSI	0-130	50-110	Green Band 50-110	1 PSI	No	Yes	No	No	No	No	No	Yes	No
Brake Pipe Press Reduct.	PSI	0-130	0-30	Green Band 0-30	1 PSI	No	Yes	No	N O	T	N E E D E D			
Equalizer Press	PSI	0-130	50-110	Green Band 50-110	1 PSI	No	Yes	No	No	No	No	No	Yes	No
Brake Pipe Press Gradient	PSI	0-130	0-110	NA	1 PSI	No	Yes	No	No	No	No	No	No	Yes
Brake Pipe Air Flow	(CFM)	TBD	TBD	NA	NA	No	No	No	No	No	No	Yes	No	No
Brake Pipe Pressure Venting	Yes/No	NA	NA	NA	NA	No	No	No	No	Yes	No	No	No	No
Loco Brake Cyl Press	PSI	0-120	0-100	Green Band	5 PSI	No	Yes	No	No	No	No	Yes	No	No
Loco Brake Cyl Venting	Yes/No	NA	NA	NA	NA	No	No	No	N O	T	N E E D E D			
Emergency Brake Application	Yes/No	NA	NA	Warning	NA	No	No	No	No	Yes	No	No	No	No
Overspeed	On/Off	NA	NA	Warning	NA	No	NA	NA	No	Yes	No	No	No	No

Table 2–5. Display Requirements Analysis (Sheet 2 of 4)

CANDIDATE DISPLAY	UNITS	TOTAL RANGE	OPERATING LIMITS	CODING	INCREMENTS	TREND INFO	ACCURACY	RATE OF CHANGE	ALTERNATIVE DISPLAY TYPE					
									Printed Matter	Annun-ciator	Digital	Round Dial	Vert. Tape	Pictorial
Penalty Brake Application									NOT NEEDED					
Fuel Qty.	Gallons	0-4000 (E - F)	NA	Red Band at "E"	1/8th Tank	NO	No	No	NOT NEEDED					
Main Reservoir Press	PSI	0-160	100-140	Red Line 100	20	No	No	No	No	No	No	Yes	No	NO
Main Res.Press. Low	No/ Yes	NA	100 PSI	Warning	On/Off	No	No	No	NOT NEEDED					
Compressor Function	Yes/ No	NA	NA	Advisory	NA	NA	NA	NA	NOT NEEDED					
Dynamic Brake Load	Amps (%)	0-800	0-800	Blue Safe Band - Red Avoid Band	20 Amps	No	No	No	No	No	No	Yes	No	No
Dynamic Brake Pos.	NA	1-8	NA	Na	NA	No	No	No	No	No	Yes	No	No	No
Speed	mph	0-100	0-80	None	1 mph	Yes	Yes	Yes	No	No	No	Yes	No	No
Speed Rate of Change	mph/s	0-10	10 mph/s	None	1 mph/s	Yes	No	Yes	NOT NEEDED					
Wheel Slip	Yes/ No	NA	NA	NA	NA	No	No	No	No	Yes	No	No	No	No
Sanding	Yes/ No	NA	NA	Advisory	NA	No	No	No	No	Yes	No	No	No	No
Ground Relay Tripped	Yes/ No	NA	NA	Caution	NA	No	No	No	No	Yes	No	No	No	No
Engine over Temp	Yes/ No	NA	NA	Caution	NA	No	No	No	No	Yes	No	No	No	No
Oil Level Low	Yes/ No	NA	NA	Caution	NA	No	No	No	No	Yes	No	No	No	No

Table 2–5. Display Requirements Analysis (Sheet 3 of 4)

DISPLAY 'S WORKSHEET

									ALTERNATIVE DISPLAY TYPE					
CANDIDATE DISPLAY	UNITS	TOTAL RANGE	OPERATING LIMITS	CODING	INCREMENTS	TREND INFO	ACCURACY	RATE OF CHANGE	Printed Matter	Annun-ciator	Digital	Round Dial	Vert. Tape	Pictorial
Water Level Low	Yes/No	NA	NA	Caution	NA	No	No	No	No	Yes	No	No	No	No
No Battery Charge	Yes/No	NA	NA	Caution	NA	No	No	No	No	Yes	No	No	No	No
Crankcase over Pressure	Yes/No	NA	NA	Caution	NA	No	No	No	No	Yes	No	No	No	No
Blower Failure	Yes/No	NA	NA	Caution	NA	No	No	No	No	Yes	No	No	No	No
Air Filter Clogged	Yes/No	NA	NA	Caution	NA	No	No	No	No	Yes	No	No	No	No
Overload Relay Tripped	Yes/No	NA	NA	Caution	NA	No	No	No	No	Yes	No	No	No	No
Turbo Air Press	PSI	TBD	TBD	Green Band Red Band	TBD	Yes	No	No	N O T	N E E D E D				
Turbo Air Press Low/High	Yes/No	NA	NA	Caution	NA	No	No	No	No	Yes	No	No	No	No
Fuel Oil Press	PSI	TBD	TBD	Green Band Red Band	TBD	Yes	No	No	N O T	N E E D E D				
Fuel Oil Press Low	Yes/No	NA	NA	Caution	NA	No	No	No	No	Yes	No	No	No	No
Lube Oil Press	PSI	TBD	TBD	Green Band Red Band	TBD	Yes	No	No	N O T	N E E D E D				
Lube Oil Press Low	Yes/No	NA	NA	Caution	NA	No	No	No	No	Yes	No	No	No	No
Grade	%	0-3	0-1.5	NA		No	No	Yes	No	No	No	No	No	Yes
Curvature	Degrees	0-12	0-10	NA		No	No	Yes	No	No	No	No	No	Yes

Table 2–5. Display Requirements Analysis (Sheet 4 of 4)

CANDIDATE DISPLAY	UNITS	TOTAL RANGE	OPERATING LIMITS	CODING	INCREMENTS	TREND INFO	ACCURACY	RATE OF CHANGE	ALTERNATIVE DISPLAY TYPE: Printed Matter	Annunciator	Digital	Round Dial	Vert. Tape	Pictorial
Slack	Slack/ Buff	NA	NA	NA	NA	Yes	No	No	No	No	No	No	No	Yes
Draw Bar Force	Pounds	0-350,000	0-200,000	Red Line 200,000	25,000 lbs	Yes	No	Yes	No	No	No	No	No	Yes
Train Mass Distribution	Tons	NA	NA	NA	NA	NA	NA	NA	Yes	No	No	No	No	Yes
Time	Hours Min. Sec.	NA	NA	NA	½ sec	NA	Yes	NA	No	No	Yes	No	No	No
Cab Signal	Red, Yellow, Green	NA	NA	NA	NA	NA	NA	NA	No	Yes	No	No	No	No
Hand Brake ON	ON-OFF	NA	NA	Advisory	NA	NA	NA	NA	No	Yes	No	No	No	No

Table 2–6. Control Requirements Analysis (Sheet 1 of 8)

CONTROLS	FUNCTIONAL POSITIONS	ACTION TYPE Cont	ACTION TYPE Discr	Present Control	Advantages	Panel Space Req.	TYPE Suggested	Advantages	Panel Space Req.	Alternate	Advantages	[illegible] Space R
Throttle Used frequently should be locate in prime space	STOP, IDLE, 1-8 (10 positions)	X	X	Lever with pointer and position indicator	Detent provide feedback on lever pos spac between detent not useable control surface. Allows a stron mechanical advantage.	11.5" x 4.25"	Selector (10 pos.)	Takes up less space than a lever	5" x 5"	Thumbwheel with position indicator	Good space economizer. Fa out idea for railroads. May be good for use with "electric choir"	4 sq/in
Speed Control	Stop, Idle 0 - 100 mph		X		Damps, oscillation in consis due to trackin rather than command	TBD	Keyboard	Space, pecision can have manual ovrd	TBD			
Direction Infrequent use only when changing direction of train movement	2 position		X	Lever	Allows a stron mechanical advantage	4" x 4.5"	Selector (3 pos.)	Takes up less panel space	3" x 3"	Toggle switch (3 pos.)	Least space of all susceptible to breakage. Requires a source of light when used at night or in poor vis.	1½" x 2"
Generator Field Only used during start and stop accessibility no problem.	On/Off 2 pos.		X	Toggle	Susceptible to breakage if visible switch position "indicates" where set. If necessary to see a light source would be req'd for nite time use.	1" x 4"	Push Button, Lighted Push "on" Push "off"	Less space	1" x 1"	Push Button Magnetic Indication		
Train Air Brake Used frequently locate in prime area	Detent positions, Off Release, Min Reduction, Service Suppression, Handle-Off, and Emergency (7 positions)	X		Lever with detents	Good mechanical advantage if needed. Allows incremental inputs between detents	11" x 12"	(1) "Hand-Wheel" Same principle as thumb wheel but larger size	Good continuous, poor for detent	4" x 6"	(2) Push Button Matrix 5 Pos only No handle off pos of Emerg.Pos. Emer. would be a separate&distinct switch plus RESET capability	Good for discrete settings. Poor for continuous settings	4^{-2} min. 3^{-2} max.

Table 2–6. Control Requirements Analysis (Sheet 2 of 8)

CONTROLS	FUNCTIONAL POSITIONS	ACTION TYPE Cont	ACTION TYPE Discr	Present Control	Advantages	Panel Space Req.	TYPE Suggested	Advantages	Panel Space Req.	Alternate	Advantages	Panel Space Req.
Train Air Brake (continued) Problem: Poor feedback of brake operation							(3) SELECTOR Rotary 5 Pos only Separate EMERGENCY PUSH BUT. "ON" and separate RESET	Good for discrete and continuous (if the environment is stable)	5.5" x 5.5" 4 sq. in. 1 sq. in.			
Air Regulation Valve Used infrequently should be accessible	Closed and open to some position defined by setting in indicator	X		Hand Wheel	Good device for controlling air or liquid flow contained in a pipe.	4 sq. in.	(1) Lever	Requires more space for installation. Visual presentation of valve setting.	3" x 3"	(2) TOGGLE (3 pos) Spring loaded to center OFF Hold in OPEN or CLOSE to obtain desired air pressure on indicator.	Susceptible to breakage	3" x 1"
							(3) PUSH BUTTON HOLD "ON" to set req'd indicator push again to "CLOSE"	Little space req'd	1 sq. in.			
Locomotive Air Brake Frequently requires prime location space.	"RELEASED" "FULL APPLICATION"	X		Lever	Good mechanical advantage if req'd. Allows for positioning between detents.	13" x 6"	(1) SELECTOR 2 pos with continuous adj in between	Saves some panel space.	6" x 6"	(2) FOOT PEDAL	Helps distribute workload to other body parts. Good feedback to operator on increasing force increments would require a separate parking brake.	0 6"x6"x6

Table 2–6. Control Requirements Analysis (Sheet 3 of 8)

CONTROLS	FUNCTIONAL POSITIONS	ACTION TYPE Cont	ACTION TYPE Discr	Present Control	Advantages	Panel Space Req.	TYPE Suggested	Advantages	Panel Space Req.	Alternate	Advantages	Panel Space Req
Locomotive Air Brake (continued)							(3) PUSH BUTTON	Continuous adjustment from "RELEASE" to "FULL" can be done electronically with time relays but would require a brake condition indicator	1" x 1"	(4) TOGGLE SWITCH Center spring loaded "OFF" APPLICATION up or forward RELEASE down or backwards would be in whatever brake APPL. or RELEASE last applied when ret'd to OFF	Susceptible to breakage continuous adj could be accomplished by hold time in a particular position. Would require a brake condition indicator.	
Dynamic Brake Frequently - locate in primo area	OFF, SET UP, 1,2, 3,4,5,6,7,8. (10 position)	X		LEVER and continuous adj between detents	Good mechanical advantage if req'd. Good "feel" feedback for positioning	9" x 3"	(1) HANDWHEEL Note: Could combine with throttle (3) SELECTOR ROTARY	See Train Air Brake		(2) PUSH BUTTON MATRIX	Input readout read clear button req'd to correct errors Input button req'd.	
Dynamic Brake Cutout Used only Start Stop. Accessibility is no problem.	OUT-IN or "OFF-ON"		X	TOGGLE SWITCH	Susceptible to breakage	1" x 2"	Incorporate as a POS on the DYNAMIC BRAKE LEVEL		2" x 3" extra	PUSH BUTTON "ON" PUSH BUTTON "OFF" (lighted)	Light given indication of switch position No projection above surface.	1" x 1"

Table 2–6. Control Requirements Analysis (Sheet 4 of 8)

CONTROLS	FUNCTIONAL POSITIONS	ACTION TYPE Cont	ACTION TYPE Discr	Present Control	Advantages	Panel Space Req	TYPE Suggested	Advantages	Panel Space Req.	Alternate	Advantages	Panel Space Req
Sander	OFF, FRONT, REAR BOTH 4 (pos)		X	TWO TOGGLE SWITCHES one to select FRONT or REAR or BOTH and the other to turn sander OFF/ON	Susceptible to breakage	2" x 2"	ON/OFF PUSH BUTTON THREE POSITION ROTARY SEL.	Conforms to HFE standards.	3.75 in.^{2}	(2) PUSH BUTTON MATRIX: ON FRT OFF BOTH REAR		2" x 3"
							(3) Tie in with direction level to govern Front or Rear sel. one On/Off Push Button	Simpliest system Doesn't allow for both front & rear sanders to operate together	1 sq. in.	(4) Same as (3) but add one more push button for BOTH ON SELECTION	Adds the BOTH ON capability to the sanding system.	2" x 2"
Traction Motor Cutout Used only during start-up or during a positive traction motor failure while operating. Keep accessible	All In 1 & 6 OUT 2 & 4 OUT 3 & 5 OUT		X	ROTARY SELECTOR 4 pos.		2" x 2"	(1) 6 separate PUSH BUTTONS MATRIX ON/OFF for each unit	Could have accidental SHUT-DOWN (all units) with this system.	2" x 3"	(2) 2 ROTARY SELS. One for even numbers. One for odd.	Could only select one engine from crash selector	2" x 8"
							(3) TOGGLE SWITCH MATRIX 1 thru 6	Susceptible to breakage. Can be accidentally shut off or on.	3" x 4"			
Engine Start Used only to start engine.	On/Off		X	(END) SELECTOR SW Toggle switch 2 pos. PUSH BUTTON GE	Susceptible to breakage	1" x 2"	PUSH BUTTON SWITCH PUSH ON PUSH OFF GUARDED	Mounted flush & guarded with a spring loaded plastic guard.	1 in. sq.			
Engine Stop	On/Off		X	TOGGLE SWITCH	Susceptible to breakage.	1" x 2"	Could be the 2nd Push Action above.	Would save putting another control on control stand.				

Table 2–6. Control Requirements Analysis (Sheet 5 of 8)

CONTROLS	FUNCTIONAL POSITIONS	ACTION TYPE Cont	ACTION TYPE Discr	Present Control	Advantages	Panel Space Req.	TYPE Suggested	Advantages	Panel Space Req.	Alternate	Advantages	[illegible]
Engine Condition	Isolate & Start/Run 2 Pos		x	TOGGLE SWITCH	Susceptible to breakage.	1" x 2"	ROTARY SELECTOR (3 pos)	Good for positive positioning and visual feedback.				
Fuel Prime				SELECTOR SW (END)			Remove from System					
Ground Reset	Normal/Reset		X	TOGGLE SWITCH Spring loaded to normal	Susceptible to breakage.	1" x 2"			1 x 1			
Fuel Pump Reset	Normal/Reset		x	TOGGLE SWITCH	Susceptible to breakage	1" x 2"					Could be hooked into start switch?	
Horn	Off Soft Loud		X	Hand Level	Confusing as to location	2.5" x 8"	2 Push buttons ON/SOFT ON/LOUD Foot Pedal	Clean addition to a console	2" x 2"	1 Push button LOUD/SOFT 1 Push button ON/OFF Push with with knee or foot)	Gives a limb thing to do	1" x 1" 2" x 2"
Bell	On/Off		X	PUSH BUTTON	Has to be operated with horn causing a problem.	2 in.²	INTERLOCK WITH HORN Bell on any time HORN is blown.	The bell cannot be operated unless the horn is blown and a shut off control is required for the bell once it is activated.	1" x 1"	PUSH BUTTON with PUSH BUTTON	Push both for horn & bell. Center switch stays engaged until hit again. Outer switch only provides input while pushed down.	
Radio Volume	OFF to HIGH	X		ROTARY KNOB	1 Assy. to operate	2" x 2"						
Radio Channel Select	No.of Channels Required		X	ROTARY KNOB	Easy to Operate	19.6"²	THUMBWHEEL	Could save some panel space. Less positive than ROTARY KNOB.	2" x 5"			
Radio Squelch	OFF, Min. to Max.	X		ROTARY KNOB	Easy to Operate	2" X 2"						

Table 2–6. Control Requirements Analysis (Sheet 6 of 8)

CONTROLS	FUNCTIONAL POSITIONS	ACTION TYPE Cont	ACTION TYPE Discr	Present Control	Advantages	Panel Space Req.	TYPE Suggested	Advantages	Panel Space Req.	Alternate	Advantages	Panel Space Req.
Headlights Rationalize this system, if you can	OFF, DIM, MED, BRITE (4 pos)		X	ROTARY KNOB	Good HFE design Switch seems OK Question the necessity for doso the operation the way they do it.	2" x 2.5"	Push Buttons.Four interlocked PB's for each pos. One set fwd. one set rear	Simple sys - Select what you want and activate proper switch.	2" x 4"	Four inter-locked PUSH BUTTONS & one Rotary Selector Switch for "Front, Both,Rear"	Requires two distinct actions to activate selected light	1" x 4" 2" x 2"
Headlight Slew	ON - OFF		X	TOGGLE	No direct control non-design use of Figure8 Off/On switch accomplishes the function in a fashion.		CHINESE HAT CONTROL. Thumb operated. Capable of movement in any direction.Return to center hold light at last switch setting.	Allows operator to place light where he wants it.	2" x 2"	LEVER capable of being moved in any direction. Return to center holds light at last switch setting.	Susceptible to breakage.	2" x 2"
Number Lights Train # Identification	Off/On		X	TOGGLE SWITCH	Susceptible to breakage.	1" x 2"	PUSH BUTTON lighted PUSH ON PUSH OFF	Saves some space Reduces breakage.	1" x 1"			
Class Lights	Off/On		X	TOGGLE SWITCH	Susceptible to breakage	1" x 2"	PUSH BUTTON lighted PUSH ON PUSH OFF	Same as above	1" x 1"			
Exterior Stop Lights	Off/On		X	TOGGLE SWITCH	Susceptible to breakage	1" x 2"	PUSH BUTTON lighted PUSH ON PUSH OFF	Same as above Would recommend more exterior lights with separate selective controls.	1" x 1"			

Table 2–6. Control Requirements Analysis (Sheet 7 of 8)

CONTROL REQUIREMENTS ANALYSIS Sheet 7 of 8

CONTROLS	FUNCTIONAL POSITIONS	ACTION TYPE Cont	Discr	Present Control	Advantages	Panel Space Req.	TYPE Suggested	Advantages	Panel Space Req.	Alternate	Advantages	Panel Space Req.
Instrument Lights	Dim to Brite with degrees of bright-dim settings between. OFF/ON	X 	 X	ROTARY KNOB TOGGLE SWITCH	Good feel for function Easy to operate	2" x 2" 1" x 2"	ROTARY KNOB OFF to ON to BRITE with degrees of bright dim settings between.	Use only one control for both functions.	2" x 2"			
Panel Lights	Dim to Brite	X		NONE			Trans-illuminated Panels-Back lit	Would require an ON-OFF DIM BRITE Switch.	2" x 2" for switch			
Emergency Lights	ON/OFF		X	NONE			Automatic	Train Emergencies of System Operating Emergencies.				
Cab Lights	OFF/ON		X	TOGGLE 1 for Eng. 1 for Brakeman	Susceptible to breakage.	2" x 2"						
Aux. Instr. Lights	ON/OFF		X	NONE			OFF/ON switch & light source	Easy to operate	2" x 2"			
Windshield Wipers	OFF, SLOW, FAST		X	ROTARY SEL. (3 pos)								
Windshield Washers	ON/OFF		X	NONE			Necessary hardware and an PUSH BUTTON OFF/ON switch for washing fluid spring loaded OFF		1" x 1"			
Thermostat	Colder/Warmer	X		NONE			House type with select & register- ing capab- ility	Simpliest system. Very little training req'd to use.	3" x 3"			
HVAC Heating, Ventilation & Air Conditioning	Heat, Vent, Air Cond.		X	NONE			ROTARY KNOB SELECTOR for sys. selection & ROTARY KNOB Sel for Sys. operation		4" x 4"		Could work in conjunction with thermostat. Above selected setting A/C comes on; below, heat comes on	

Table 2–6. Control Requirements Analysis (Sheet 8 of 8)

CONTROL REQUIREMENTS ANALYSIS Sheet 8 of 8

CONTROLS	FUNCTIONAL POSITIONS	ACTION TYPE				Panel	TYPE		Panel			Panel
		Cont	Discr	Present Control	Advantages	Space Req.	Suggested	Advantages	Space Req.	Alternate	Advantages	Space Req.
Headlight Control	OFF, Dim, Med, Brite		X	ROTARY SELECTOR	Small Space Req.	4" X 4"	Dual Lever	Allows Greater Flexibility.	2" X 6"			

It is appropriate to reiterate at this point, based on our review and analysis as presented in the previous paragraphs, that in spite of the wide variation in cab designs, the principal crew functions are quite similar in maneuvering and managing the train. Furthermore, because of the complex mix of operating conditions as described in Section 1, line-haul freight operations do constitute the most complete set of functional requirements. It should be recognized, for example, that if only yard-switching operations were considered, entries in the matrices would necessarily be modified. Dynamic braking, for instance, would no longer constitute a significant task, and humping would be added as a function. In addition, viewing of instruments would decrease significantly. The conclusion that line-haul operations pose the severest test for the locomotive is further supported by the observation that railroad supervisors may routinely assign older locomotives to yard-service or branch operations when their performance in line-haul service falls below par.

Therefore, the line-haul functions delineated in this section constituted our formal recommendations for further development, and this development is presented in the next section.

3. DETAILED DESIGN

3.1 INTRODUCTION

This section presents the steps taken to achieve the design suitable for further development. The process is illustrated by the flow chart shown in Figure 3-1. It is initiated by a detailed human-engineering analysis of the cab requirements as set forth in the preceding section. The design evolved as a function of inputs from the contract technical monitor. As the design progressed, our projections for the next 10-15 years of changes in locomotive subsystems, train handling procedures and potential for automatic devices such as Automatic Train Control (ATC). Constraints were identified, too, and, as we will show, are reflected in the recommended design. The constraints include equipment origin and those stemming from carrier operating procedures and federal regulations where appropriate. Within these constraints, a variety of alternative designs were generated. Although each of the alternative designs was judged worthy from a human-factors standpoint, one was selected for further development on the basis of cost, reliability, safety, occupant protection and crashworthiness. The design approach is presented in the next section, followed by design considerations and discussion of detailed components.

3.2 DESIGN APPROACH

The first item to be discussed in this section is the projections made on the 10-to-15-year technical and operational progress in the railroad industry. It must be immediately stressed that the process of deriving these projections will continue for the life of the contract. One reason for this is that hardware development programs are constantly being introduced to meet the changing needs of the railroads. Other reasons include software development such as the AAR Track-Train Dynamics program in identifying new solutions to old problems; test programs, such as those carried out by TSC; changes in public attitudes in putting a higher premium on updating railroads; the energy shortage, forcing changes in train handling to optimize fuel consumption; and the fact that government funding and regulation are in a state of flux. With all these factors contributing to the requirements for train handling and methodology, it has been difficult to pin down an exact projection of the state in train handling c. 1990. In fact, it may be suggested that the results of this contract may be one of the factors contributing to future changes. Projections of changes in train handling and control requirements expected to occur within the next 10-15 years were made so that the present cab design would reflect them. Projections prepared considered a number of inputs from different sources. These were:

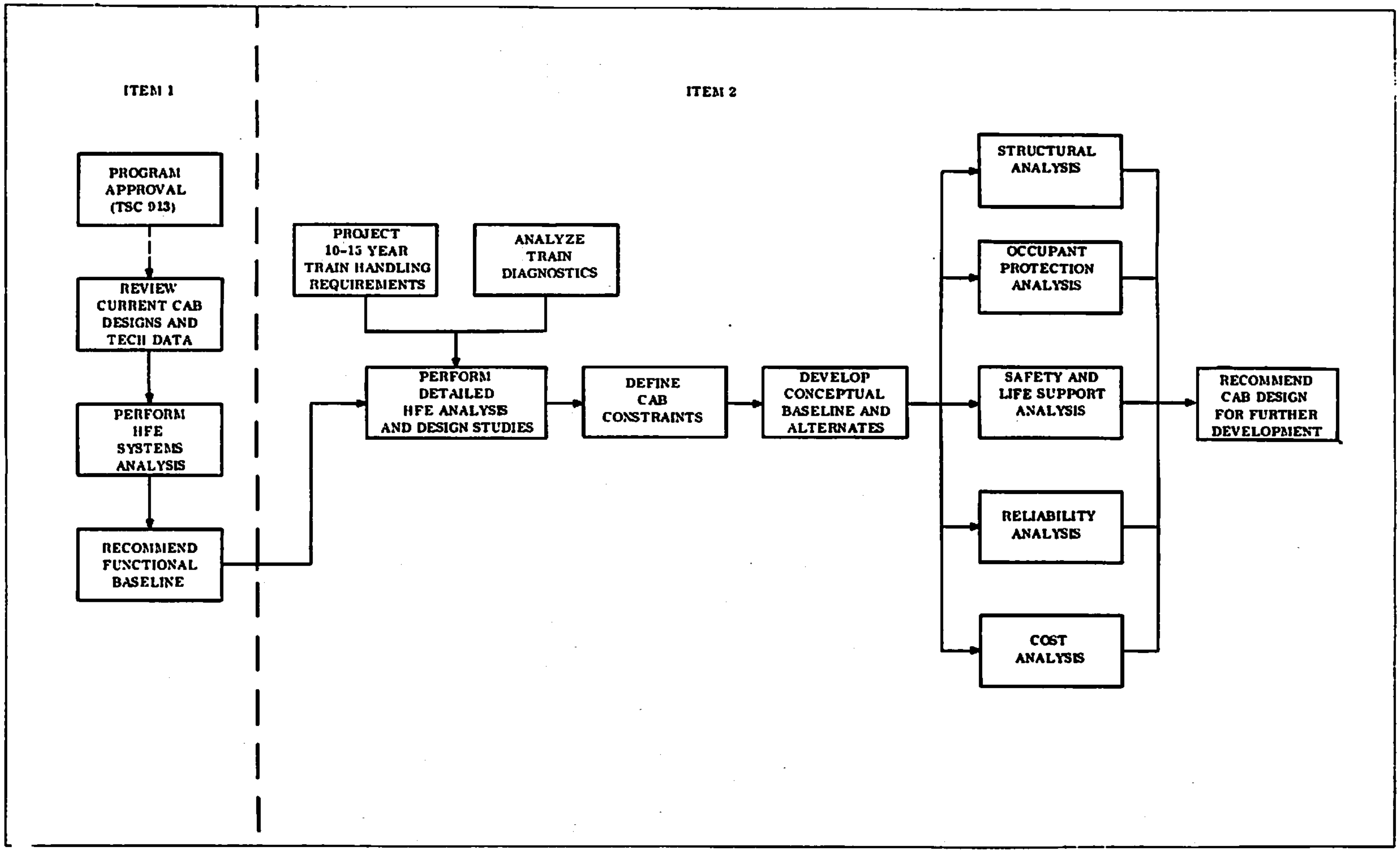


Figure 3–1. Locomotive Cab Design Development Functional Analysis Through Recommended Cab Design

a. Trends identified by EMD
b. Trends foreseen by operating personnel
c. Developments stemming from the Track/Train Dynamics Program
d. Survey of present and planned TSC studies of railroad operations
e. Projections made in trade journals and periodicals
f. New equipment being developed by manufacturers.

As previously mentioned, projections are likely to change as new programs are started and old ones completed. However, some confidence in the validity of the projections resulting from the above sources may be gained where there is some consensus of operating personnel. Actual hardware or procedures are at least under study in the development phase and at a state of accomplishment wherein their implementation is reasonably probable by 1990.

Some projections were made on the basis of informal surveys of railroad management personnel when asked to "crystal ball" the future. Their comments are briefly summarized below.

a. Bulk commodities may tend to travel in longer, slower trains with an increased use of helper consists.
b. Merchandise commodities may tend to travel in shorter, faster, more frequent trains.
c. Electrification may get increased consideration if a lack of oil resources continues to be a problem.
d. Locomotives may tend to be higher in horsepower ratings.
e. Increased use of computerized freight yards may make mass train-distribution information more readily available to engineers, and freight cars may be blocked for optimum track-train dynamics rather than simple destination blocking.
f. Locomotive engineers may have the use of more train-handling aids such as draft-buff, air flow, drawbar force, and track profile indications.
g. Increased use of simulators in training will raise the skill level of new enginemen.
h. Advances in electronics and reduced cost of mini-computers and microprocessors may have an effect on sophistication of locomotive control systems.
i. Pneumatically operated brakes will probably undergo little change and will remain the primary braking system for quite some time due to their fail-safe design, ease of maintenance, and relatively low cost.
j. Traction motors as a source of axle power will probably become more efficient due to changes in technology but remain essentially unchanged in basic function and configuration.

Once both present and anticipated requirements were defined, the functional baseline was modified for design development. At the most general level, certain functions are not likely to change. For example, multiple-unit operations will still be practiced by many railroads, and helper consists will be used to negotiate upgrades and provide additional horsepower along the train. Train speeds will probably always vary from very slow passing through yards, on curves, undulating terrain, and negotiating turn-outs, to maximum allowable speeds on straight-level runs over well maintained track. We do not foresee freight trains even approaching the actual and desired speeds envisioned, for example, by Amtrak in the next 10-15 years. It is equally obvious that locomotives will continue to be operated in diverse environments, such as subzero weather on the one hand and desert climates on the other. In addition, snow, ice, fog, rain, floods and obstructions (debris on track) will always be a problem, as will the necessity to operate both day and night schedules.

The bi-directional capability of modern locomotives will still be an important aspect of the modern freight-carrier mission and not likely to change. Communications rules are currently under reappraisal by the FRA, and new rules or modifications of existing rules are a certainty as railroading becomes even more complex. At the very least, communications equipment and techniques are likely to improve. Automation of operating procedures and data collecting and storing has made strong inroads in yard-control and train-control procedures, and some additional provisions will have to be added to the engineer's repertoire to manage this additional source of information. However, the study uncovered no data which indicated that automation will eventually replace the engineer. He does and will continue into the foreseeable future to perform a vital function. This is true because of such variables, for example, as the mixes of loads, age of car, high/wide loads, loads that require special handling by the engineer such as explosives, combustibles and volatile cargos.

While we recognize the utility of the unit trains and the complete automation of the train-handling functions in a few applications, these appear to be special cases of train-handling solutions rather than representative train-handling techniques of either the present or the near future. The analysis revealed that train crew tasks at specific levels were also unlikely to change very much. By subsystem, the critical tasks are and will continue to be associated with maneuvering the train, monitoring the exterior environment, managing the propulsion system, braking the locomotive, monitoring the track-train situation and signals, and managing auxiliary systems, engine systems, dynamic braking, and pneumatics. Within each subsystem as is shown in Section 2.0, certain tasks are more important than others. An examination of the tasks required to manage the train revealed the following order of priority:

a. Application and release of tractive effort;
b. Monitoring speed and power/force indications;
c. Setting the direction of locomotive travel;
d. Activating generator field;
e. Monitoring the status of traction motor temperature.

On the other hand, when the train air-brake system is the object of consideration, all tasks are practically the same in relation to successful mission accomplishment including monitoring the brake-pipe pressure during normal reductions and to identify abnormal leak rates, monitoring brake pipe flow, applying and modifying brake-pipe status and pressure, pressure venting, and monitoring the equalizer reservoir and the brake-pipe pressure gradient.

A caveat is proper at this point. The study team found no data, with the exception of TSC test car data, that measured actual engineer behavior on representative routes on which we could base our analysis. The objective in determining how important certain tasks were to the engineer in accomplishing his mission was to provide some preliminary design criteria for laying out the cab working area. Our analysis must be interpreted in this light. Qualitative and more meaningful data could only be obtained through observing a proper sample of engineers at their tasks for significant periods of time and under representative routes and conditions. This was beyond the scope of the present study.

3.3 DESIGN CONSTRAINTS

Design contraints were identified based on the survey of locomotive cab designs and train-handling requirements. These were:

a. Braking
b. Propulsion
c. Track/train dynamics
d. Man/machine interface

The air-brake systems currently in use on line-haul freight trains are the 6SL, the 24RL, and the 26L. Improvements in air-brake systems have been made over the years as new techniques have evolved and hardware has been developed. For example, the 26RL brake equipment provides a minimum-service reduction position with a predetermined initial reduction in brake-pipe pressure after which further reductions are initiated and controlled by the engineer. Neither the 6SL nor the 24PL equipment provides this feature. Additional modifications to braking equipment are likely to be in common use, e.g., the ABD car control valves which will directly affect train handling. Therefore, the present cab design was developed to be compatible with existing and anticipated air-brake hardware on locomotives and rolling stock.

Two types of dynamic brakes are currently employed in locomotive cabs: taper and flat. The amount of retarding force developed with the taper system is controlled by the speed of the locomotive and the position of the brake lever. The higher the speed, the greater the retarding force for a given throttle position. The amount of retarding force developed with the flat system is controlled solely by the position of the dynamic brake lever. The lever must be placed in notch #8 position to develop maximum retarding force. This system has been adopted by the AAR because when using it the engineer regulates the braking effort with the control and does not have to think about relating his dynamic braking effort to the speed of the train. Instead, he monitors amperage on the load-indicating meter. For purposes of the present study it was assumed that the engineer will be travelling in lead locomotives of locomotive consists that contain units having both types of braking, at least until the older locomotives are retired from main-line service. It is also assumed that extended-range dynamic braking (in the 23-mph to 6-mph range) will become more common.

Based on the review of locomotive designs, it was concluded that propulsion systems were not likely to undergo any fundamental changes, although there is a trend toward higher-horsepower locomotives. It was judged that concern for optimum use of fuel resources would necessitate that power plants be shut down when the locomotive is idle more often than is current practice.

Track/train dynamics will continue to play a significant role in train handling. Over the long term, more stable consists are likely to be encountered as train make-up philosophies are changed and track and right-of-way conditions improve. However, since the value of any new concepts in train handling must ultimately be demonstrated in service applications, it is assumed for purposes of this design that road engineers will encounter a wide variety of train-handling variables which will affect their train-handling performance. For example, placement of heavy cars and light cars in trains and the result and impact on draw bar forces, braking are lateral forces between wheels and rails. Freight cars also vary in their load capacity, dynamic stability and physical dimensions.

Finally, any new cab design must conform to additional constraints affecting the man/machine interface. For example, the maximum free volume is physically limited by AAR clearance envelopes. Visibility from the cab must allow the engineer and crew maximum forward, lateral and rearward fields of vision. Cab designs and crew tasks must be structured to conform to safety regulations and communication procedures and be revised in the light of future requirements as they may arise during the next decade.

3.4 SELECTION OF DESIGNS

The question arises as to what additional requirements could be reasonably postulated as belonging in the cab of today and the near future; and what criteria should be considered in cab designs.

First, a strategy was adopted to bound the problem. To preclude a "utopian" approach, four constraints were imposed on any candidate for inclusion, as follows:

a. It should improve the safety of the cab occupants or at least not degrade it beneath acceptable and desirable standards.
b. It should show promise in improving train handling with some demonstrable potential such as reducing loss and damage.
c. It should significantly improve the locomotive cab as a working and living environment.
d. Its cost should be reasonable.

Three concepts were selected for further analysis and development. The first concept was a human engineering design based on the aforementioned currently-known functions; that is, the cab of today. Secondly, a design was prepared, which we termed the maximum-performance cab, which contained all of the advances in state-of-the-art crew-station design and train-handling procedures that could be identified and were within reason.

The final question to be resolved was what should be developed further. The third cab design concept falls between maximum-performance and HFE functional cab.

A number of locomotive cab design configurations were developed. In general, these alternative configurations were selected to provide relatively wide-ranging differences in features and layouts. This wide range of configurations meant that significant differences were evaluated, rather than different variations on the same theme, as might have resulted if an initial configuration was judged to be "obviously best".

Conceptual drawings were prepared for each configuration. These included three-quarter-view perspectives, three plan views and detail drawings of particular features.

Each alternative was evaluated for its suitability in meeting the following criteria:

a. Fulfillment of Functional Requirements
b. Compliance with HFE Design Criteria
c. Occupant Protection
d. Structural Evaluation
e. Reliability
f. Safety
g. Reasonable Cost

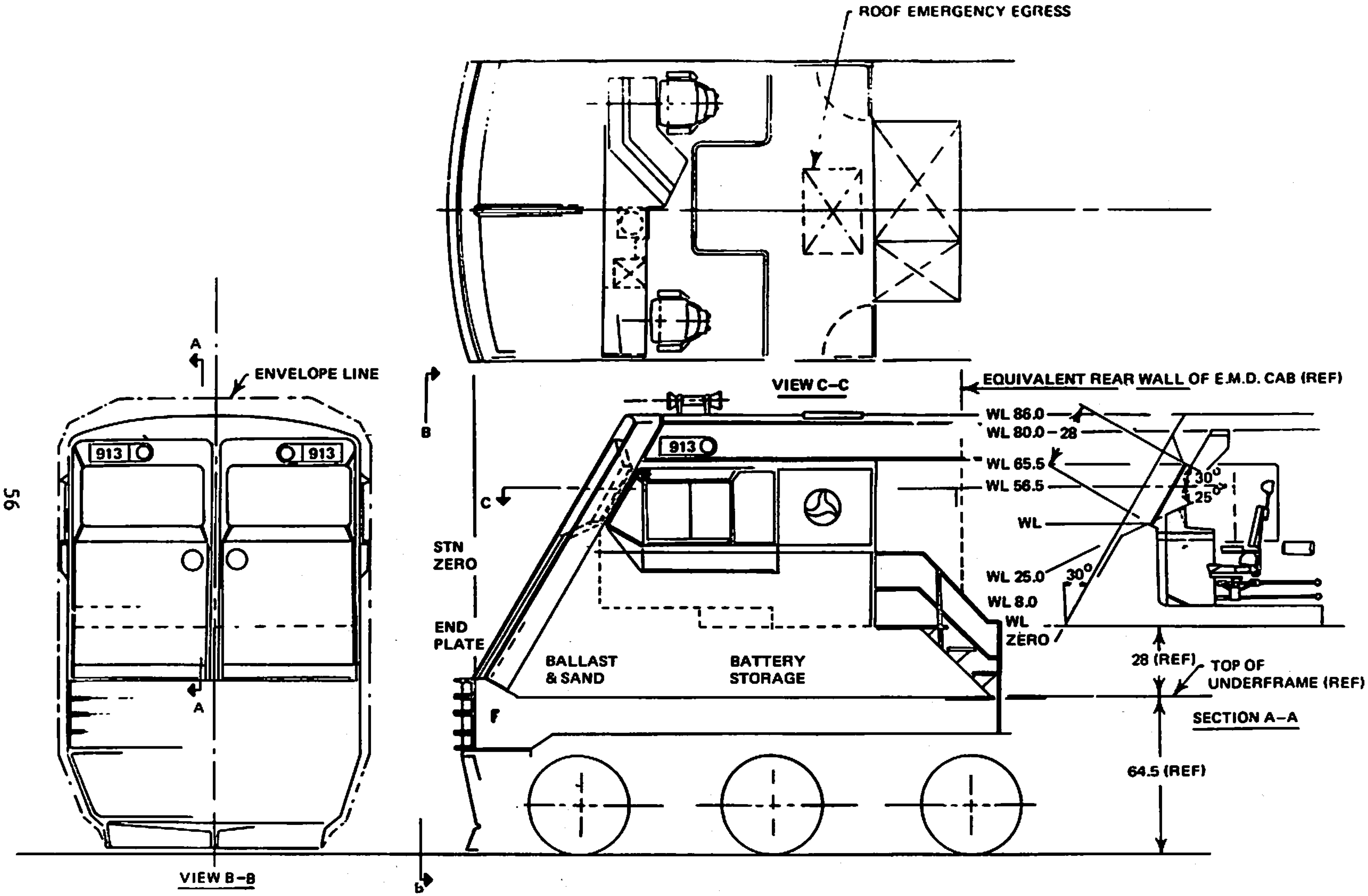


Figure 3.2a. Recommended Cab Design Layout

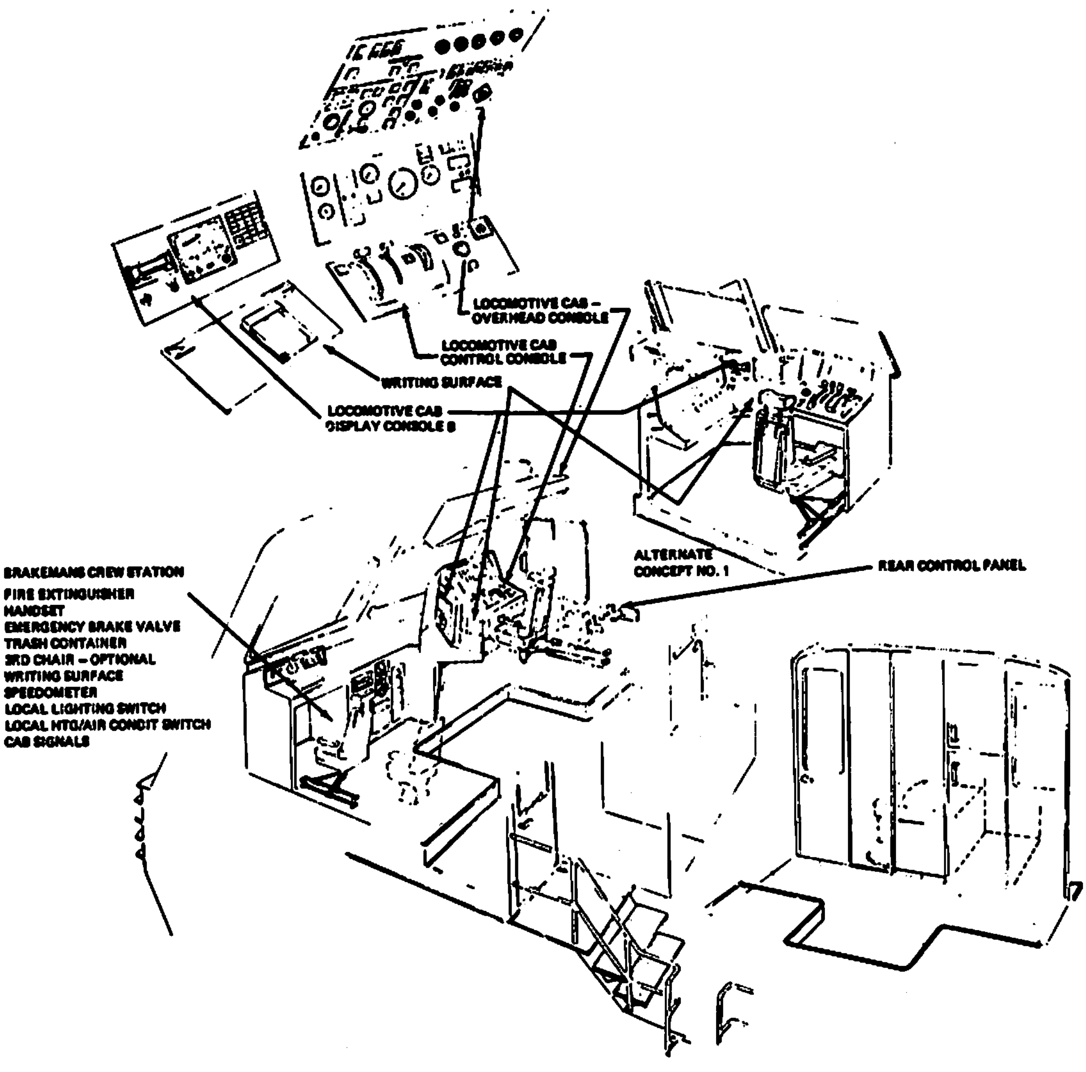


Figure 3–2b. Recommended Cab Interior Arrangement

The recommended cab design is the one that best satisfies the seven criteria. This design was further refined by evaluating design features on the basis of the effect of cab/locomotive interfaces on improved workspace utilization, life support, and environmental control.

As a cross-check on the design, a soft mockup was constructed reflecting an evolving design and was evaluated by Boeing and TSC human factors personnel.

3.5 CAB DESCRIPTION

The cab interior is shown in Figure 3.2a. The interior dimensions are based on the following rationale. The cab width was set at the maximum possible within the constraints imposed by place C of the AAR clearance envelope. This was done to provide good visibility when looking out of the side window back along the train and through the rear door window when moving in the direction of the long hood. The height of the cab was also limited by the clearance envelope. In addition, the requirement to seat the engineer as high in the cab as possible to provide good forward visibility and provide standing clearance for the 95th-percentile crewman was considered. The cab was made as long as possible for several reasons. First, volume was required to accommodate a lavatory, a refrigerator and storage space with easy access. Second, sufficient space is necessary between the engineer's seat and the lavatory wall, so that personnel may leave the cab quickly and without being blocked. Third, the large volume provides for growth items such as an additional crewman or new equipment. The cab is 10 feet 8 inches wide, and cab roof height is 14 feet 9-1/2 inches, measured from the top of the track rail.

The cab interior arrangement is shown in Figure 3.2b. The dimensions are as follows:

	Cab Height	
	Cab Centerline	Crew Station Centerline
1st Floor	7'1"	6'8"
2nd Floor	6'5"	6'0"

The cab length measured from the front bulkhead to the rear wall (cab exit point) is 9 feet 3 inches. The floor area is approximately 170 square feet, while the free volume is approximately 590 cubic feet.

The front end of the locomotive cab is sloped at an angle of 30° with a vertical anticlimber located just below it. Figure 3-2b, view B-B, reveals a two-piece front windshield and provisions for number lights, class lights and headlights.

Personnel enter and leave the cab through two rear doors which lead to a platform and steps. Side windows are of three-piece construction.

A perspective sketch of the interior arrangement can be seen in the lower right corner of Figure 3-2b. As shown, the engineer and brakeman are seated side by side with the brakeman on the left. General outlines are shown of a two-section work console for the engineer and an overhead panel. To the rear of the engineer's seat are a swing-out reverse-operation control panel and a phantom outline of the engineer's seat rotated 180 degrees from its normal position.

The cab floor is shown in View C-C of Figure 3-2b and in the perspective sketch to its right. The floor is a split-level design so that the crew are seated as high as practical and maintain a proper relationship to the cab floor for ingress and egress under normal and emergency conditions. At the extreme right on the drawing is shown the back wall of the cab, containing the lavatory, storage facilities and the refrigerator.

This brief description is presented to introduce the cab design to the reader. The detailed analysis and design rationale that produced the concept are presented in the following sections.

3.5.1 Detailed Engineering Analysis

Various sources of information, including aircraft and military data, served as guides throughout the design phases. Since the train engineers' functions are many complexly related variables associated with specific hardware configurations and the operating environment, such as track/route constraints and train loads, we attempted to sort out the appropriate categories to which these variables could be assigned for systematic study and inclusion in the design. The design approach was "inside out", starting at the crew station and working toward the cab envelope. The order of analyses is as follows:

a. Vision
b. Anthropometry
c. Seating
d. Work Station
e. Primary Controls & Displays
f. Secondary Controls and Displays
g. Habitability
h. Cab Envelope

Finally, problem areas existing in present cabs were reviewed for potential impact on the new design and ran the gamut from desired usable volume to safety hazards such as protrusions, sharp edges, loose objects, and failures to secure trap doors.

3.5.2 External Vision

The definition of a locomotive cab crew's external-vision envelope posed an interesting problem to the design team. While a great deal of information exists pertaining to design criteria on many of the components of the crew station, no criteria were available to aid in the design of windshields and side windows of a locomotive. Military standards are quite specific in setting forth the design requirements for various aircraft, but the viewing envelopes of pilots and engineers are not comparable. Therefore, it was necessary to develop a set of visibility criteria and derive a forward visibility envelope of pilots and engineers are not comparable. Therefore, it was necessary to develop a set of visibility criteria and derive a forward visibility envelope to meet them. The first item to be accomplished was to define the seeing tasks. This was done by making a list of external objects that the engineer must look at while operating his locomotive. A representative selection of these objects is presented in Table 3-1.

The selected items are listed according to their locations along the right-of-way in front of the train. The height of the object was then noted and ranged from objects on the track to bridge signals 45 feet above the track.

To initiate the design, an arbitrary point was selected, called the design eye. The design eye point was defined as an arbitrary fixed point in space. It is a constant throughout the design, and all other components of the cab are designed in relation to it. It is the assumed point at which the engineer's eye (external canthus) is located under operational conditions. The design eye point was located in three dimensional coordinates and the height and distance of target objects were used as inputs to a computer program which was developed to calculate the visual angle from the design eye to points along the apparent visual path of the target objects while the vehicle is moving. These calculations resulted in the azimuth and elevation values of the targets as they "moved" along. From these values the visual angle subtended from the design eye were plotted as shown in Figure 3-3.

Operating procedures were reviewed to determine the minimum distance at which objects along the wayside must be seen. The minimum was set at 50 feet from the front end of a locomotive using one boxcar-length as a rule of thumb. From the figure it can be seen that for viewing an overhead bridge signal 50 feet away an elevation angle of approximately 40 degrees upward is required. In the case of a switch point at track level a 25° downward viewing angle is required. The operational scenario of a line-haul freight locomotive was again reviewed to determine the lateral vision requirements. It was concluded that since the engineer is likely to encounter grade crossings, multiple trackage and curves in the rail as severe as 10°, the lateral vision should accommodate these requirements. Additional considerations

TABLE 3-1. LOCOMOTIVE ENGINEMAN FORWARD VISION REQUIREMENTS SELECTED VISUAL TARGETS

ITEM	LOCATION	HEIGHT IN FEET
Fuses	On Track	0
Grade Crossing	On Track	0-13
Switch Point	On Rail	0
Bridge Signal	Above Track	45
Pot Signal	4 ft from Rail	1.5
Switch Stand	5 ft from Rail	1
Switch Stand	5 ft from Rail	6
Grade Crossing Signal	8 ft from Rail	7
Mast Signal	8 ft from Rail	15
Mile Post	8 ft from Rail	4.5
Track Side Sign	8 ft from Rail	6
Grade Crossing Approach	Track Side	0

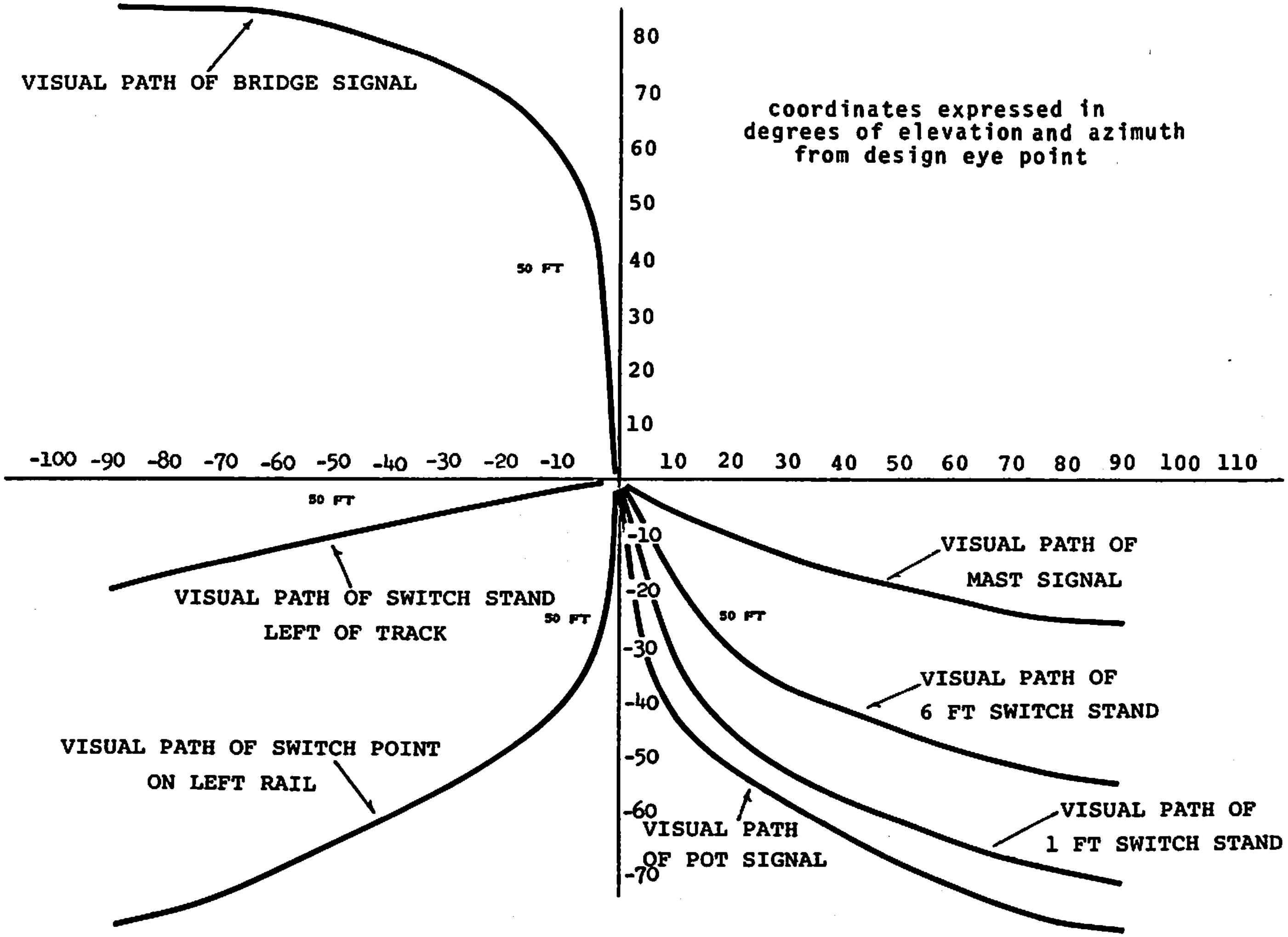


Figure 3–3. Locomotive Engineman Vision Requirements

were that if the total cab width was constrained by plate "C" of the AAR locomotive cab envelope, the brakemen would have the same field of view as the engineer; and crashworthy requirements dictated the use of collision posts which would not limit the crew's forward vision.

It became apparent during the design activities that some modification of the requirements was necessary. The downward vision angle was retained because of the importance of the engineers' attention to people and all objects on the ground. The upward vision was decreased to 30° because larger windshields were severely constraining the crew-station design. In the recommended design the overhead panel could not be placed within an optimum reach envelope without interfering with external vision. During design reviews some concern was also expressed about the "greenhouse effect" that larger windshields might have, and the possibility that sunlight would shine directly on the engineer when the sun is overhead. With this in mind, a re-evaluation of the vision requirements was made and it was found that a 10° decrease in the upward vision angle would slightly compromise the engineman's external view. An overhead birdge signal would be visible at 55 feet away instead of 50 feet away.

To evaluate the potential significance of this reduction in viewing distance a series of windshield plots were prepared for monocular (design eye) viewing, stationary binocular and binocular with head movement perspectives. These are shown in Figures 3-4, 3-5, and 3-6. Figure 3-4 is a rectilinear monocular engineer-window plot showing windows and collision posts. It should be noted that there are no obstructions protruding into the visual area. Figure 3-5 is a binocular plot of the same area; here it should be noted that the collision post appears smaller because the interpupillary distance using binocular vision provides the ability to "see around" objects. Figure 3-6 introduces an additional variable, namely, head movement. The analysis also determined that if the engineer moved his head forward (this is not an unreasonable assumption, because he is unrestrained) the effective upward visual angle returns to 36°. It should also be noted that the windows on the opposite side of the cab appear smaller because objects subtend smaller visual angles as they move further away. The side windows are discussed in detail in a later section.

It was concluded that the 10° decrease in the upward visual angle was acceptable, thereby allowing the overhead panel to be placed in an advantageous location and would better serve the cab crew.

The external-vision analysis later was modified to include factors such as the train engineer's looking out the side window foward and backward along his train; as mentioned, this is discussed in a later section. The engineer was provided with excellent vision of the terrain and train features. Fatigue and strain caused by excessive head movement in observing everything from either side of cab was reduced.

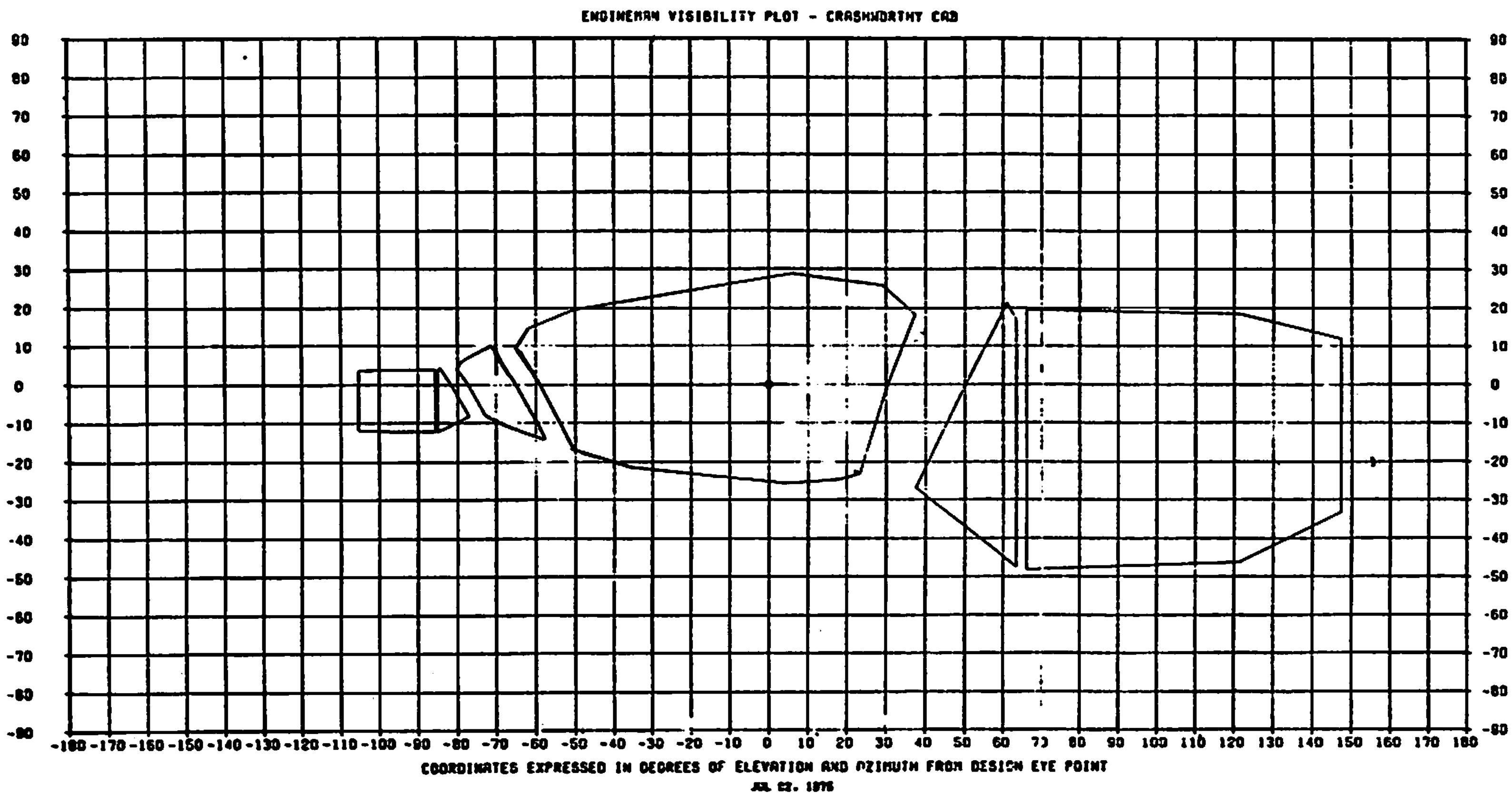


Figure 3—4. Monocular Vision Plot

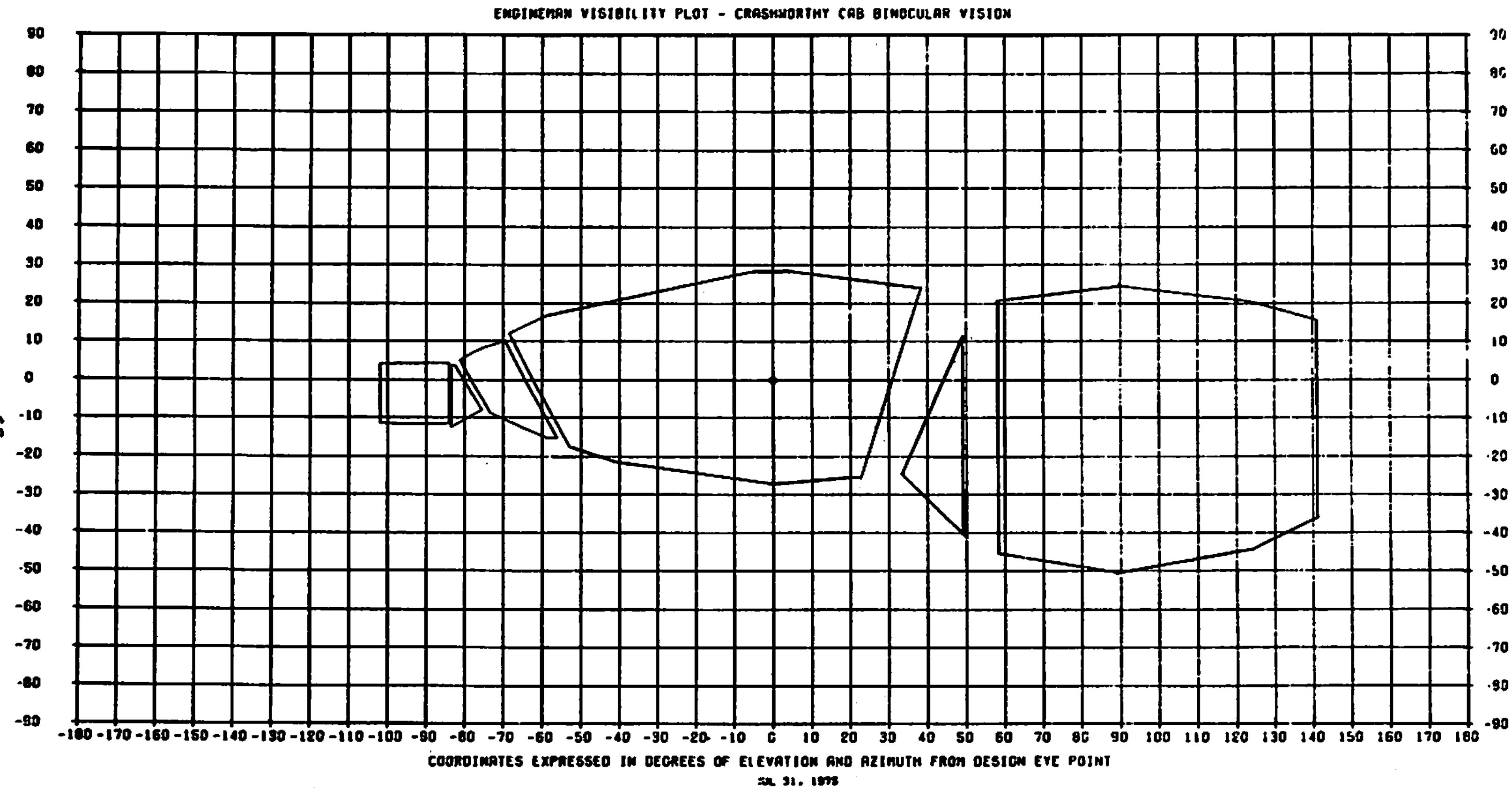


Figure 3–5. Binocular Vision Plot.

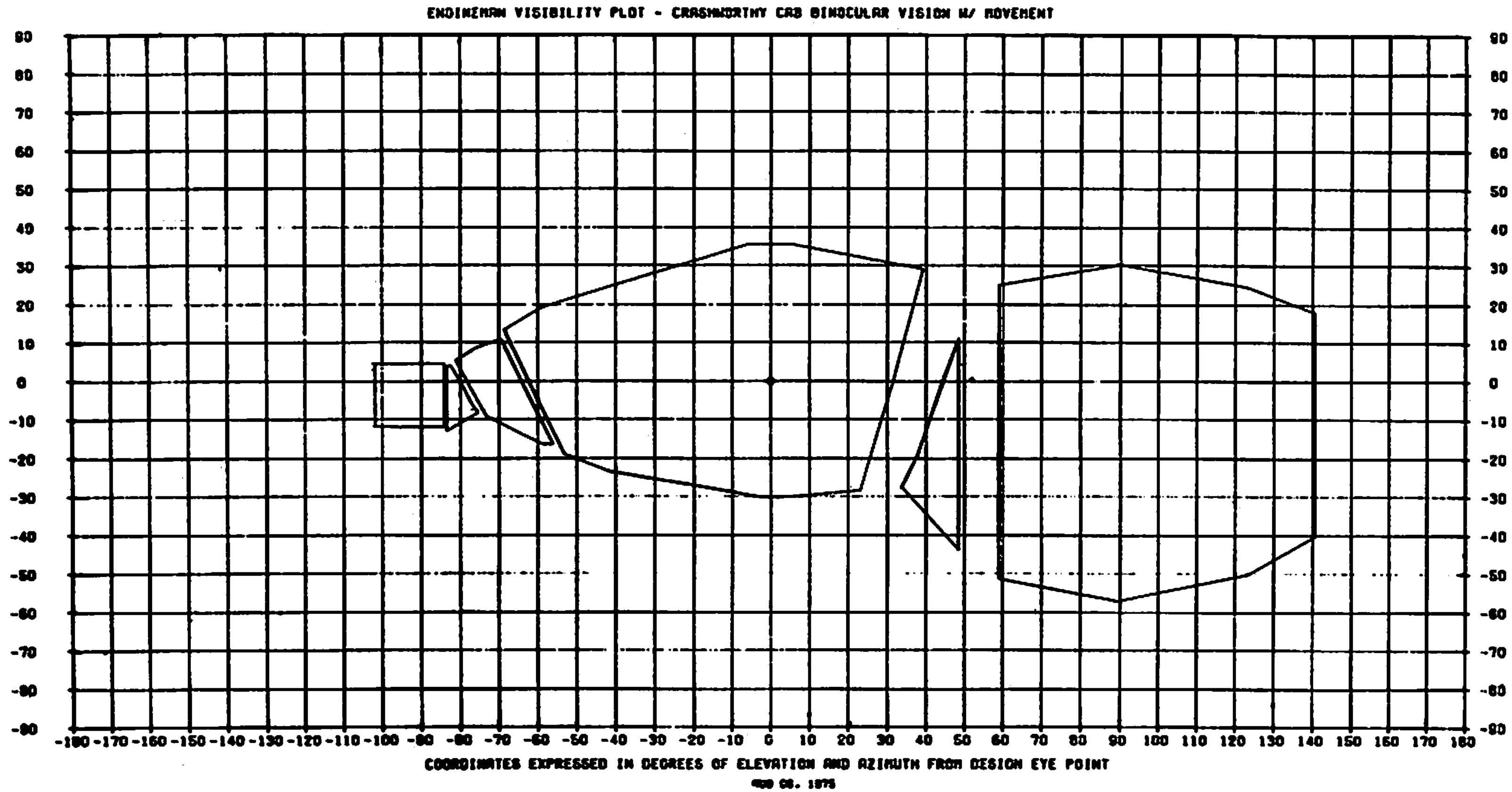


Figure 3–6. Binocular Vision Plot with Head Movement

The dimensions of each of the two windshield panels are 28 inches high by 50 inches wide. The total area is approximately 19½ square feet, which is greater than the area (approximately 12½ square feet) found in operating cabs.

Windshields should be vandal resistant, i.e., made of material that will not shatter when struck by foreign objects, and the material must not be able to be scratch during normal cleaning and maintenance. Attention should be paid to the quality of the windshield in the areas of deviation, distortion, luminous transmittance, haze, and anomalies. Specifications for these qualities, and testing procedures, may be found in USAAMRDL Technical Report 73-19, March 1973, Goodyear Aerospace Corp., MIL-G-25871A, and MIL-P-25374A. Data from these sources will be summarized in the DOT/TSC-913 Locomotive Cab Design Guide. A pantograph-type windshield wiper is recommended because of its ability to describe a wider arc and keep the wiper blade in a perpendicular position. Defogging and deicing may be accomplished in a number of ways. Forced hot air, heated windshields, and special coatings are feasible methods, but caution should be exercised. Forced hot air is the conventional method of defogging, but power consumption, noise, speed of action and coverage have traditionally been problems, although not insurmountable ones. Heated windshields have proven themselves to be an acceptable alternative, but the optical qualities, expense and reliability of these windshields are of some concern to the design team. Also, the diffraction that may be present with embedded-wire type, and the light attenuation properties of the gold-coated type have not been evaluated for locomotive applications as much as the design team would like. Special coatings that prevent fogging are currently available, but their optical qualities and durability are not well understood. Rather than state the superiority of one of the methods described above, we recommend that a parametric evaluation of each of these techniques be conducted in the context of the controlled locomotive environment to determine the best method that should be applied to the design of a development locomotive cab.

The side windows in the cab are of a three-piece construction. The forward triangular section has the ability to swing out a short distance to ventilate the cab and act as a wind wing. In the closed position, it will latch positively to provide a seal against the external environment and the intrusion of foreign objects. The center and end sections of the window are on tracks to enable the window to be unlatched and slide rearward. A ratcheting device is in the sill to keep the window from inadvertently sliding shut in the case of a run-in. These two sections of window are designed in this manner so that in cold, hot or rainy weather, the engineer can open the window for his use only as much as needed and quickly shut it again. A window that opened down, as an automobile window does, would require the window to be fully open when the engineer needs to communicate with ground personnel or look down the side of the train. A window that opens upward was considered hazardous because of the guillotine effect of the glass in case the raising mechanism fails. These side windows should be made of a material that will have some thermal insulating properties similar to the Canadian LRC train. They should be of a quality that will not scratch easily or shatter under impact from a foreign body.

3.5.3 Anthropometry

The design eye continuing as a reference, the next step was to determine the engineer's body envelope. Since no systematic data are known to exist concerning the physical anthropometry of locomotive engineers as a distinct population, the dimensions used in this study are those of the adult male population of the United States. The 95th-percentile male dimensions were used to set maximum clearance distance, while the 5th-percentile dimensions were used to set such things as reach envelopes to assure that the controls and displays on the crew station are accessible to all crew members. Figure 3-7 shows some typical dimensions that were used to calculate reach zones for a 5th-percentile man's reach.

The rationale for choosing the segment of the population between the 5th and 95th percentiles is that experience has shown that these design boundaries provide the designer with the best chance of being able to use good design practices while accommodating the greatest number of users. As an illustrative example, past experience has shown that if the population boundaries are widened to include 1st to 99th, a panel close enough for a first percentile is uncomfortably close for a 99th. Also, there are extra costs involved in designing for a larger population (i.e., longer seat adjustments), and design penalties are incurred. It should be noted too that the anthropometric dimensions have changed over the years and are likely to change in the future, suggesting that data bases should be obtained and updated periodically.

3.5.4 Seating

The subject of a seat for the locomotive engineer deserves some discussion. As has been noted, a typical work shift for an engineer is twelve hours, and since most of the operator's time is spent seated, his perception of the work environment is greatly affected by the degree of comfort afforded by the seat. To provide a seat that will stabilize the engineman's body so he can work efficiently, some general criteria must be met. The ischial tuberosities should bear much of the weight of the individual, while excessive pressure on the thighs should be avoided. Proper lumbar support should be provided to avoid fatigue. Lateral support for both the back and the thighs should be provided, but not to the extent that the engineer cannot shift his posture frequently. Proper seat depth, width, and height

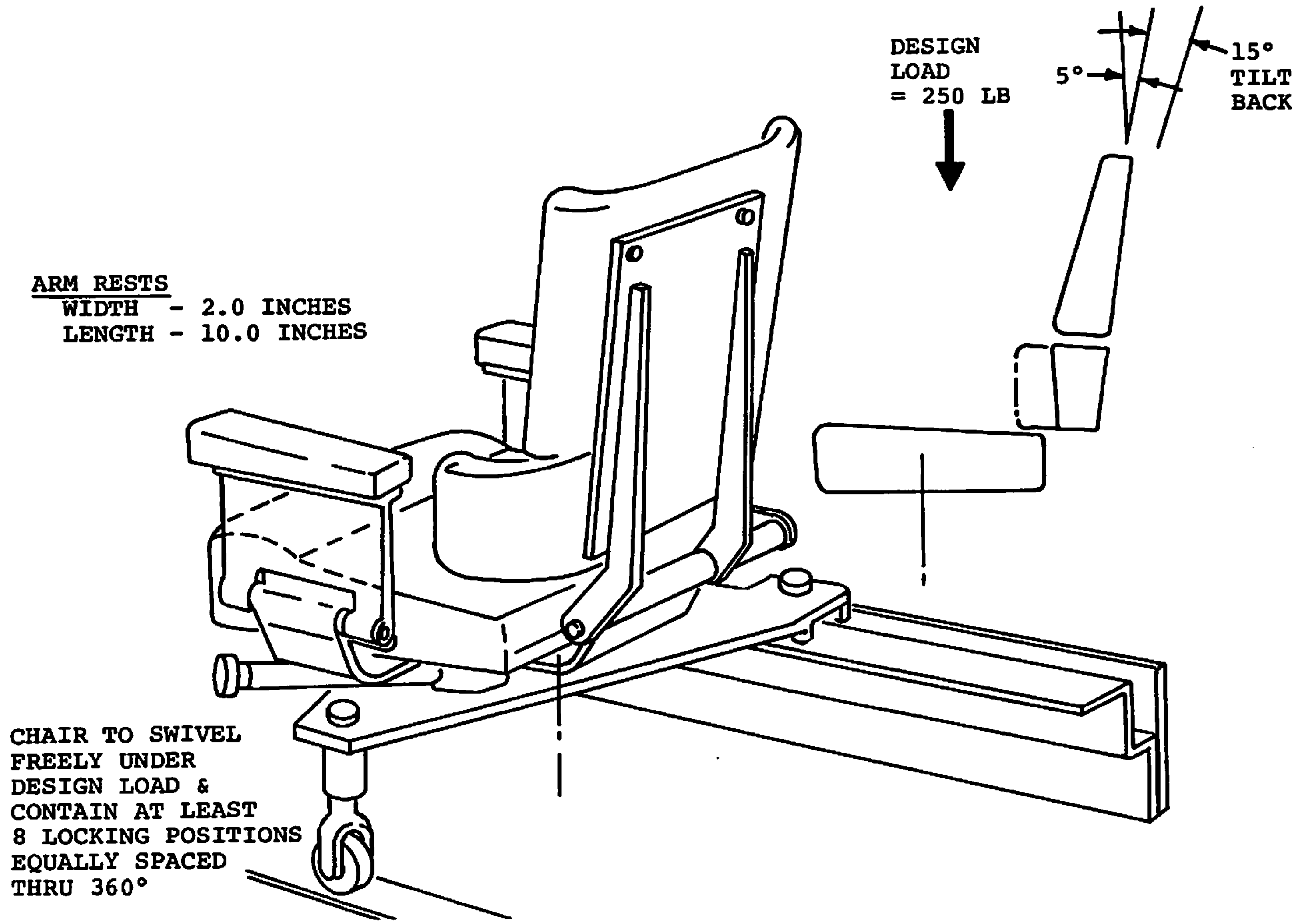


Figure 3–7. Crew Seat Design Requirements

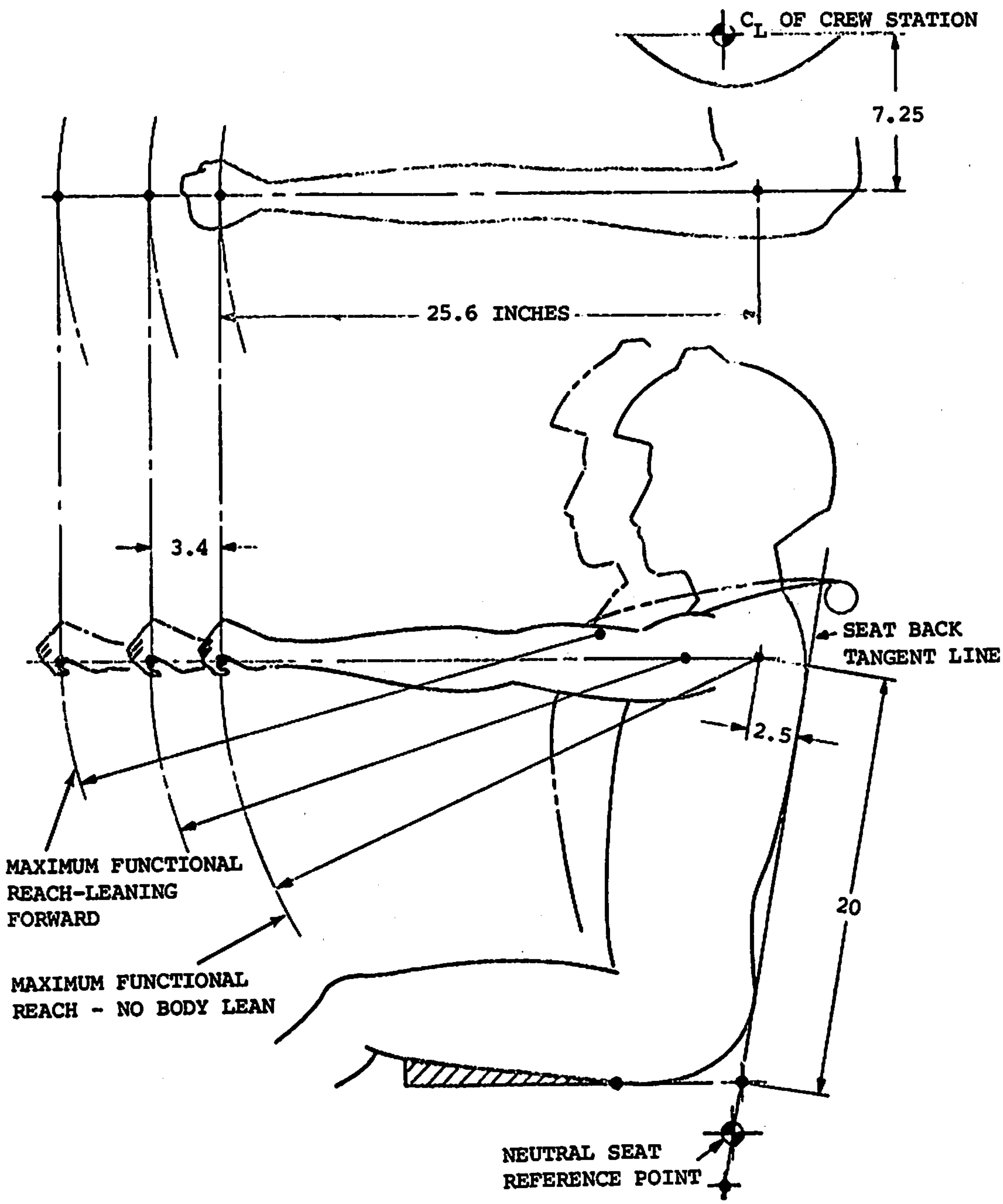


Figure 3–8. Functional Reach Envelope – Minimum Percentile

should be geared to the dimensions of the population being accommodated. Seat adjustments fore and aft, as well as up and down, from a vertical reference point are necessary to allow operators of different statures to position themselves in a manner that will provide access to all controls and assure proper external visibility. Particular attention must be paid to ingress and egress from the seat, and the requirement to look back along the train would seem to indicate that a swiveling seat is necessary. A seat back angle of 15° is generally recommended to ensure the comfort of the crewman over a prolonged period without giving him an overly relaxed feeling that may contribute to decreased vigilance.

Figure 3-7 shows how all the above requirements can be combined to arrive at the design of a crew seat. This seat is conceptual in nature and is meant to be an example of the implementation of the set of criteria shown in Figure 3.8. It is suggested that before any seat is adopted for use by the locomotive engineer, it should be thoroughly field tested in a variety of operational and environmental conditions. Particular attention should be paid here to appropriateness of the seat-covering material for proper heat and moisture dissipation, and the durability of cushions and seat structure. Of special significance is a head restraint on the back of the chair positioned so as to prevent whiplash in case of a severe run-in but not capable of being used as a head rest.

3.5.5 Primary Controls and Displays

The primary controls and displays and their rationale for inclusion in the design are the direct result of the functional analysis presented in Section 2. While the analysis did give indications of what controls and displays were needed to operate a line-haul freight train, there were times when the final choice was based on a subjective evaluation of the facts. This usually occurred when two or more choices in spite of all the analysis. For this reason both the selected items and alternatives, in some cases, will be discussed.

3.5.6 Engineer Consoles

The configuration of a console for the present locomotive cab is dependent upon cab envelope, train operating requirements, and the following human-factor requirements.

a. Visibility outside of workplace
b. Visibility inside of workplace
c. Primary control access
d. Secondary control access
e. Support of body elements
f. Clearance of body elements
g. Clearance for personal equipment
h. Restraint of the body
i. Protection from injury.

Also, in considering the design of a locomotive cab incorporating human-factors engineering-design criteria, an order of priorities is generally established. The priorities used here are as follows:

a. Primary visual tasks: This refers to both external and internal objects. Eye position relative to the task establishes the basic layout reference point.
b. Tasks which interact with primary visual tasks: In the case of a locomotive these would be power control and braking. Emergency controls also fall into this category.
c. Control/display relationships: Controls should be near the displays they affect, and should have a direction of movement compatible with movements on the display.
d. Arrangement of workplace elements: Anticipating sequence of operation will help determine the arrangement to preclude "hopping" between one control and another.
e. Convenient placement of workplace elements: The most important item here is frequency of use.

The standard AAR console is located in the cab so that the controls on it are operable when the engineer faces forward, sideways or to the rear. The study team observed that when he faces rearward, the operation of the controls is awkward, so this location cannot be considered optimum. Accommodation of rearward use of the control console prevents optimum operation when facing forward. The present console and controls and displays are compromises to satisfy operating requirements. Since rearward operation on the average is a small percentage of the total operational time of a line-haul freight train, it was decided that the basic design should concentrate on optimizing console design and arrangement for forward operations of the train. A rearward movement capability would then be provided through the use of repeater controls to facilitate road switching.

Once the design eye was placed, a body envelope was determined and a seat was established, consideration was made for the placement of controls and displays. Due to the functional interfaces between the present cab and present operational practices that require the engineer to read signals that are primarily on the wayside receiving train orders from manned stations enroute, and the necessity for communicating with ground personnel during yard or switching operations that require moving the locomotive in reverse, a ground rule was established early in the design process to retain the position of the engineer on the right side of the cab. Using HFE design guides and the anthropometric data, boundaries and clearances for the work station were roughly drawn up keeping in mind the type and number of controls and displays identified in the functional analysis. The primary reach and internal vision areas directly in front of the engineer were reserved for the main controls and displays. A secondary area to the operator's left was reserved as a neutral zone to be used as a writing surface, or for the placement of official papers, such as train orders or train mass distribution diagrams, or personal items such as coffee cups and ash trays. The overhead reach zones are utilized for less frequently used displays and controls. Dimensions for the control and display panels, as previously mentioned, were constrained by external vision lines that could not be interfered with.

Seeing tasks were defined and a determination was made of configuration and location of each crew-station item required to implement the visual functions. Controls, displays and work station geometry was allocated to conform to specific reach envelopes and were successfully demonstrated during soft mock up reviews and analysis.

The primary instruments and controls are located directly in front of each crew member on the design-eye axis for ease of viewing. These instruments and controls are approximately 28 inches away and well within the crew's primary visual field in accordance with accepted standards.

The secondary displays are located to the left of the engineman and are also included in his primary visual field. It should be noted that these displays are so placed that they do not intrude into the external vision envelope.

The auxiliary systems displays and controls along with the remote consist controls are located above the primary console. Careful consideration was given to the placement of individual items so that the engineer would not have to move his head or eyes excessively to read instruments and identify control positions.

3.5.6.1 Engineer's Primary Displays

The primary displays, as previously noted, are located directly in front of the engineer. As shown in Figure 3-9, this display panel, which is 8 inches high and approximately 24 inches wide, contains the following items:

a. Speedometer
b. Power/drawbar force indicator
c. Equalizer reservoir and brake pipe pressure indicator
d. Brake-pipe venting annunciator
e. Emergency brake on annunciator
f. Brake-cylinder pressure indicator
g. Main reservoir pressure indicator
h. Brake pipe air flow gage
i. Cab signal
j. Time-speed-distance calculator

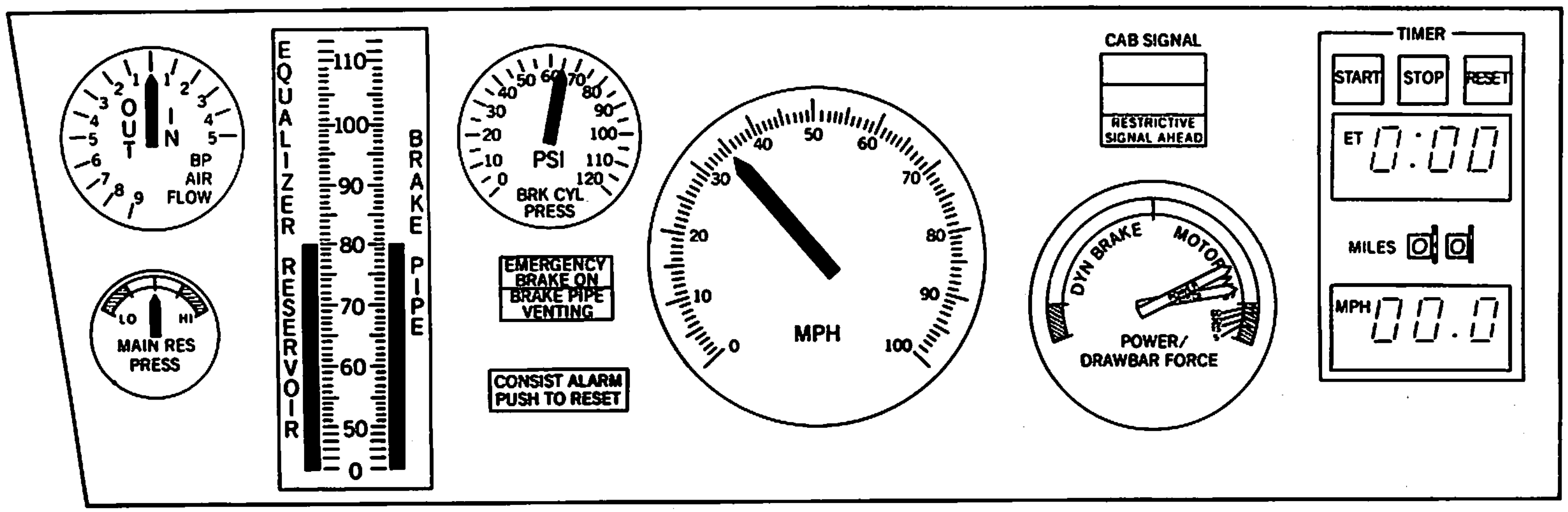


Figure 3–9. Primary Design Display Panel

3.5.6.1.1 Speedometer

The speedometer is the most critical display in the cab, and therefore it was located directly in front of the engineer. A round instrument was selected as opposed to digital readouts or vertical scales. The reason for this resided in the nature of the information content required; that is, trend information is a significant parameter because the engineer must do considerable advanced planning for his train handling. If his train is approaching a restrictive zone at a speed greater than that permitted, he must begin to brake the train to achieve the appropriate speed prior to entering the restrictive block. His rate of slowing added to his knowledge of the allowable distance to be travelled enables him to plan his brake application to minimize buff and draught forces that could damage his lading. The rate of change information is equally important. When he has left the restrictive block and is permitted to increase his speed, he must not build up speed at excessive rates because of the possibility of a break in two. This trend information is readily available from a moving pointer indicator while difficult to extract from digital displays. A vertical scale instrument was not practical in this application because of the long scale length that would be required to meet the functional requirements. The speedometer was laid out in a number of configurations and the most readable design was a 5-½ inch round dial instrument. One-mile-per-hour graduations were provided (a half-mile resolution), and each ten miles per hour were numbered.

The 5½-inch diameter is admittedly a rather large instrument, but the sizing and spacing of indicia require quite a bit of space to lay out an instrument for the 100-mph range provided. While freight trains do not run anywhere near 100 mph at present, it was projected that merchandise commodities may run at these speeds in the future. The sizing and spacing of the indicia was optimized so as not to be cluttered and to be read easily at the nominal 28 inches' viewing distance.

3.5.6.1.2 Power/Drawbar Force Indicator

This display is located to the right of the speedometer, and its function is to guide the engineman's use of the throttle. On the first iteration the indicator displayed amps on its face as is traditional in present cabs and had a color-coded red line for both motoring and dynamic braking. An operational review of the use of the loadmeter dictated a harder look at the requirements of the engineer. The loadmeter has many functions, none of which appears to require the use of the numerical values on the dial face. These ampere values are only meaningful when the throttle position and speed, as well as the number of traction motors, are integrated to evaluate the performance of the locomotive. To believe that the locomotive engineer can perform these calculations whenever any of the parameters change is stretching a point. Rather, he makes a cursory inspection of these parameters to assure that all values are within their limits. In accelerating, decelerating, and maintaining speed, the critical value on the loadmeter is the maximum continuous and short time rating lines. For these reasons, the traction motor loadmeter was configured with a green band for the safe zone under dynamic braking, and red bands to denote the avoid regions in either case, with short-time ratings clearly marked. A round-dial, moving-pointer display was chosen because of the need for detecting qualitative changes and rate of change of the traction motor load.

During further detailed analysis of the traction motor loadmeter it also became clear that this display had one major shortcoming in terms of giving the engineer enough information to do his job. The loadmeter tells the engineer the characteristics of the traction motors of the locomotive he is riding. If all other locomotives in the consist are of the same class and type and are performing normally, then the loadmeter will reflect the true status of the locomotive consist. However, this situation is quite often not the case. It is not unusual to have a mix of locomotive types in a consist. Also, the engineer's job is made more difficult because he must mentally compensate for the differences in locomotive types when moving the throttle. A second shortcoming of the loadmeter was that while it displays a rough estimate of the locomotive's power output, it does not give a good picture of the drawbar force being generated by the entire consist.

To overcome these disadvantages in the loadmeter, a display concept similar to the Power-Force Indicator currently being tested by the railroad was designed to indicate the drawbar force generated by the consist. On the first layout of the dial face the pounds of force were arranged from zero to 350,000, with a red band from 250,000 to 350,000. An identical scale was then added so that either buff or draft force could be determined. It readily became apparent that these numbers were extremely cumbersom and that their operational meaning to the engineer was questionable. A different approach was tried where the force was displayed in percent, with 250,000 pounds being the 100-percent mark and values exceeding that point constituting an overload. This arrangement was judged as more satisfactory, but the utility of the values under 100 percent became questionable. The engineer is interested only in the fact that he has not exceeded the maximum rating of the draft gear.

Intermediate values, while significant from a system engineering standpoint, appeared to have no functional utility. Therefore, it was concluded that a green "safe" band for motoring, a blue "safe" band for dynamic braking, and two red bands to denote the "avoid" region in either case were needed. Then, when the drawbar force meter is used with the loadmeter, the engineer can more effectively handle his train because he is now able to take advantage of all the power under his command without the risk of breaking or damaging equipment. In addition, it should be recognized that an additional input to this indicator could be made by a device calculating the L/V ratio at the coupler to regulate drawbar force on curves. However, no such device is present on today's trains.

Since function and configuration concepts are similar and due to the confusion of look-alike instruments positioned on a panel with limited space, a single instrument was used to indicate both functions. The instrument, as shown in Figure 3-9, is round in shape, uses a dual concentric needle, and is called a Power/Drawbar Force meter. The operating bands are color-coded as described above, and the needles are each labeled to indicate the parameter being displayed. The engineer will then be able to determine at a glance that his traction motor load and drawbar force are within safe limits and govern his throttle or dynamic brake accordingly.

3.5.6.1.3 Equalizer Reservoir and Brake Pipe Pressure Indicator

The equalizer reservoir and brake pipe pressure indicator are located to the left of the speedometer. The brake pipe pressure (BPP) indicator is critical from the engineer's viewpoint, since this is the main indicator of the operating status of the train's brake system. Nominal BPP ranges from 70 to 110 PSI. A full service reduction from 70 psi to 20 psi making the required operating range from 50 psi to 110 psi. Pressures under 50 psi would occur as a result of an over-reduction in brake pipe pressure; but these yield no change in performance and therefore are usually of little interest to the engineer during a run, except that he may wish to note the event. Equalizer reservoir pressure is a predictor of BPP and used to guide the engineman's control input to the system. Therefore, the scale requirements for both BPP and equalizer reservoir pressure (ERP) are the same, and it was determined that one scale could be shared by both indicators. Functionally, the ERP indication is used to make control inputs and does not really reflect any system performance characteristics. The BPP does reflect system performance, and follows the changes in ERP. For these parameters a vertical scale indicator displaying both ERP and BPP was chosen. The scale between 0 and 50 psi was compressed showing 10 psi increments, as was the scale between 110 and 130 psi, to allow maximum resolution in the functional range of 50 to 110 psi. The vertical indicator was chosen because the literature recommends it when the engineer must read and know the absolute value of a specific parameter, and rates of change must be displayed. The two adjacent parameters can also be quickly compared in both the static and the dynamic states.

3.5.6.1.4 Brake Pipe Venting and Emergency Brake Annunciators

To aid in system monitoring, a brake pipe annunciator was included on the panel. In present locomotive cabs the engineer can hear the brake pipe vent as some air is directed into the cab. This feature has both advantages and disadvantages. For one thing, the engineer is presented with a direct auditory cue as to the status of the air brake system. In fact, a short auditory cue when a long one is expected during a full service reduction may indicate a discontinuity in the air brake system. Through experience, engineers learn to utilize this information as a diagnostic tool on the status of the health of their airbrake systems, and they often rely on it almost to the exclusion of the brake pipe gauge, even though in theory they are not supposed to.

The venting is disadvantageous for several reasons. First, the air brake venting can be described as consisting of a loud "hiss or whoosh' which lasts approximately for the duration of the reduction. This noise has many high-frequency components and is quite loud. It is well known that exposure to excessively loud noises for long durations over a period of time is detrimental to hearing, although no audiograms of engineers were known to exist that would indicate that engineers are impaired. Second, the air entering the cab through the vent may bring in pollutants. It was learned that in some instances oil particles were vented into the cab's atmosphere. Dust and sand that has invaded the cab may be blown about and enter the crew's respiratory systems or get into their eyes; this is clearly a hazard to health and safety.

To preserve the necessary information while eliminating the undesirable side effects, an annunciator was selected which comes on and stays on for the duration of a brake pipe reduction. It should be recognized that an auditory input to the engineer would also be suitable and even desirable. However, it was assumed that with the necessity to communicate and to provide a relatively quiet environment, an auditory signal might be an annoyance. However, in the event that future cab development reveals that a visual overload condition exists for the engineer in the present cab design, an auditory signal would require serious attention.

Beneath the brake pipe vent annunciator is an emergency-brake-on annunciator. This annunciator is energized either by an engineer-initiated emergency-brake application or a system-initiated application due, for example, to a malfunction. The annunciator remains on until reset by the engineer using the reset function on the brake handle, as will be discussed in subsequent sections.

3.5.6.1.5 Brake Pipe Airflow

The information conveyed to the engineer by means of this indicator is the rate of airflow in the brake pipe. Since rate information is what the engineer is looking for, a round-dial instrument was chosen. The markings on the face are not meant to indicate any absolute values but only relative indications of flow so that the engineer can determine if his brake system has stabilized or is in a state of flux. Also, brake pipe leakage is indicated to advise him of problems in the brake pipe.

3.5.6.1.6 Brake Cylinder Pressure

Brake cylinder pressure of the locomotive is displayed on a round-dial instrument with five-psi increments. This instrument gives the engineer information on the increases and decreases of air pressure in the brakes on the locomotive only. He is able to determine brake cylinder pressure to a maximum of 120 psi, as well as the rate of change (fast or slow).

3.5.6.1.7 Main Reservoir Pressure

Main reservoir pressure is a system parameter over which the engineer has little control, but of which he must be aware. Sufficient pressure must be present in the reservoir for the pneumatic brake system to operate. Low pressure will constitute a safety hazard in that insufficient pressure will be available to apply brakes. Overpressures, on the other hand, may result in component failures, leaks, and premature wear of compressors. Therefore, rather than provide the engineer with numerical values, a color-coded band was provided with over and under pressures in red and a safe zone in green. An indication of low pressure can be rectified before a run begins by increasing engine rpm to "pump up" the train more quickly. En route, either a high or a low pressure indication when BPP is static is indicative of a malfunction and may require the engineer to stop the train depending on the operational situation.

3.5.6.1.8 Cab Signals

Cab signals have been included on the main display panel because of their importance in governing the engineer's behavior, particularly in situations where wayside signals may not exist. In the present design, they have been placed high on the front panel and close to the center line of the crew station. This display provides multi-colored cab signals lighted in the same manner as annunciator lights, or, in addition, a multi-message display could be used to display the signal in a written and color-coded format. The intent here is to provide a clear, compact display that will retain the signal under which the train is operating. One extra feature of this cab signal is that an indication is given when the next block will have a more restrictive signal. In this way, the engineer will be able to plan his activities more effectively when he knows that the next block may require him to slow down.

3.5.6.1.9 Time-Speed-Distance Calculator

The final component on the primary display console is a time, speed, distance calculator. A set of stop, start, and reset buttons is available at the top to control the timer, whose digial, display appears immediately below it. The distance traveled in the time interval can be dialed in the windows below the elapsed time readout, and average speed will be displayed in the bottom digital display. This display can be used to calibrate the speedometer, keep track of short time ratings in traction motor red zones, or check brake pipe leakage during air brake tests.

3.5.6.2 Primary Controls

Located directly below the primary displays is the primary control panel, which relates the controls to the displays functionally. This panel is shown in Figure 3-10 and contains the following items:

a. Train Brake
b. Independent Brake
c. Throttle
d. Manual Sand
e. Stop All Engines
f. Direction Lever
g. Emergency Stop
h. Bell
i. Console Lock

3.5.6.2.1 Train Brake

One of the first questions to be dealth with was the relationship, from a functional standpoint, between the train (automatic) air brake control and the independant (locomotive) brake control. The automatic brake when applied on present locomotives normally applies brakes to the locomotive and train when a service reduction is made. The independent brake applies the locomotive brake only. If the engineer does not desire an application of the independent brake when a service reduction of the automatic brake is made, he "bails" the locomotive brake off so that it will not apply (prevents a brake cylinder pressure buildup). He does this by pushing his independant brake handle down while making a service reduction with his automatic brake system. However, by the same token, an engineer can apply the locomotive brakes with the present controller independently of the automatic system.

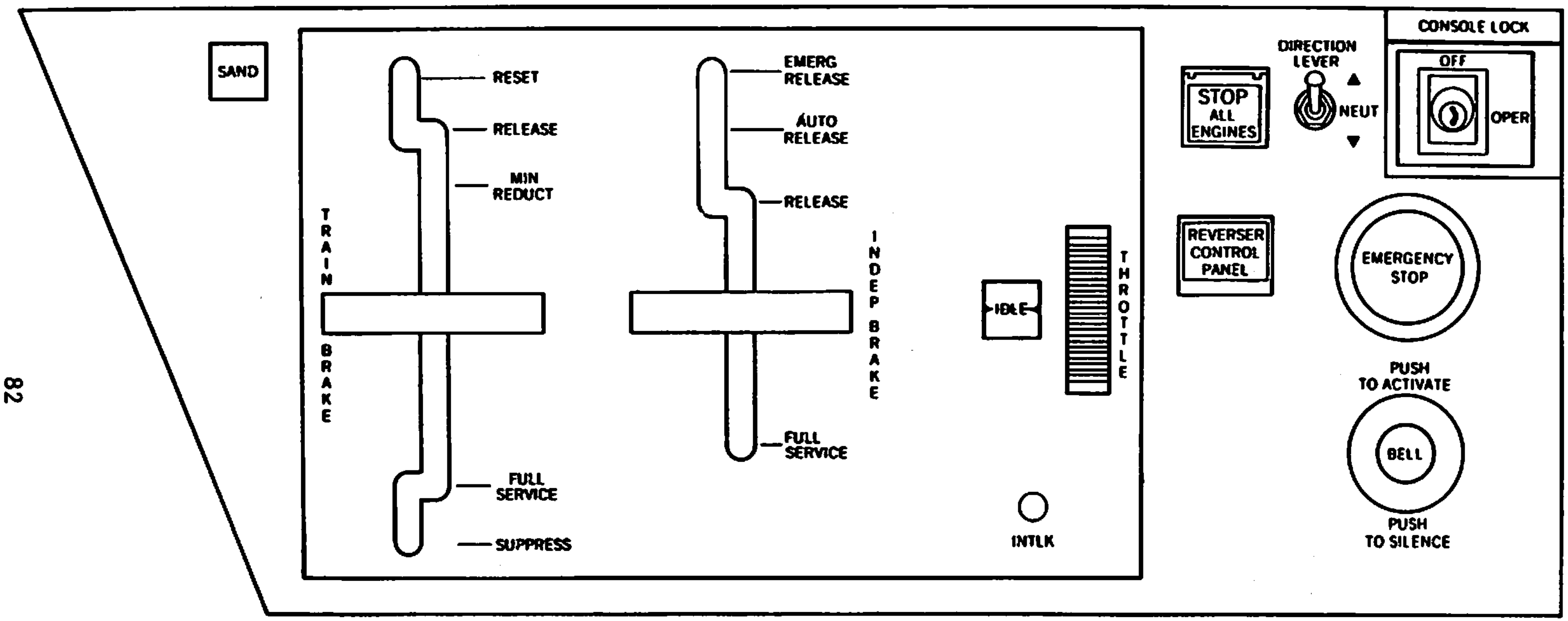


Figure 3—10. Primary Control Panel

Some assumptions were made with respect to these controls. It was assumed that the lever-type controls for the primary functions were suitable with some modification. It was determined that the use of levers would cause fewer problems for present-day engineers in changing over from the traditional console to the proposed one. Use of the levers permits control "throws" equal to those used on today's trains. While the levers are oriented in a different plane, their travel distance will be familiar. The use of the arc and the curved surface from which the controls jut will also aid the engineer because he can use the curved surface "to feel" his control location while paying attention to other things. The lever-type controls are the train brake and the independent brake.

Several means of implementing these functions were considered. Some candidates considered were lever, slide, and hand control knob. The hand control knob was rejected because review of the human-factors literature and the applicable specifications revealed that it is not particularly suitable for making fact-control inputs such as instant brake application. The selection of the control lever was made for the following reasons: (1) It is easily coded for differentiation by color, size, labeling, location or shape. (2) Lock or stay positions can easily be provided by the use of detents and (3) A combination lift-up action and detent can be used for lever positions that are not frequently used and in which inadvertent positioning might be hazardous. (4) The operator can "feel" the position of a lever as it passes through its arc in deference to a slide which does not convey this feeling. The other controls are very different from what they are on today's train but nonetheless are within reach and easily operable by the engineer.

During a ride in an E-44, it was observed that the engineer bailed off the independent brake on almost all occasions when the automatic brakes were applied. The exceptions occurred when the train was in a terminal maneuver, and in these instances the enginer permitted the independent brake to apply along with the automatic brake. It is significant to note that the task of bailing off occurs when the engineer is maneuvering his train and managing his draft and buff forces, requiring his simultaneous attention to the train brake, the dynamic brake, the throttle, and their attendant displays.

Since a single observations is admittedly insufficient, we sought a way to provide more data on the engineer's real behavior with respect to air brake systems.

Because TSC had recorded these engineer responses during representative operational runs using its test car, we borrowed a sample of their data for analysis to see if further information could be developed on this point. In this larger data sample, it was observed that of all the brake pipe pressure reductions made on the four tapes examined, approximately 87% were accompanied by a bail-off of the locomotive brake cylinder pressure. On this basis it was concluded that the locomotive engineer, given present cab controls, spends considerable time initiating an action that has two functions: decreasing brake pipe pressure and increasing brake cylinder pressure. He then takes a second action to inhibit part of the first. For these reasons, then, good HFE design practices indicate that the application of the locomotive brake should not have to be inhibited for every application of the train brake. The train brake functions implemented for the present design are as follows:

a. <u>Reset</u>
The reset position is used when an emergency brake application has occurred. Setting the lever to reset enables the engineer to recover normal train braking functions.

b. <u>Release</u>
Selection of this function releases the train brakes and allows the brake pipe pressure to return to its nominal value.

c. <u>Minimum Reduction</u>
Minimum service reduction of about six pounds occurs when this function is selected.

d. <u>Full Service</u>
Full service reduction allows a full application of the train brakes. In between a minimum reduction and full service positions, a continuous range of reductions is permitted.

e. <u>Suppression</u>
This function is selected to make a recovery after a penalty brake application.

3.5.6.2.2 Independent Brake

The independent brake is shown in Figure 3-10 and shows the functions to be discussed below.

<u>Autorelease and Release</u>
The Autorelease function is the position farthest forward. When the independent brake is set in this position, the locomotive brake will automatically bail off; that is, it will not apply during an application of the train brakes. The engineer must make a decision that a build up of locomotive brake cylinder pressure is or is not desirable with a brake pipe reduction. If the decision is that he wishes to make a series of controlled inputs to the train brakes, the lever must be placed in autorelease position. After his tasks are completed and the train brake lever is placed in release, the independent brake will revert to release and would require a second action to reinitiate the "bail-off" process. The advantage of using this system is that the engineer need only decide which function he wants and execute it once, rather than continuously bailing off as is done in present cabs. It should also be noted that the concept permits the engineer to initiate the bail-off function when the automatic brake lever is in the intermediate position. The rationale for the implementation of this control device is the same as for the selection of the automatic brake handle.

3.5.6.2.3 Throttle

The throttle control contains the following functions:

a. Idle
b. Motoring
c. Dynamic Braking
d. Dynamic Brake Interlock

These functions have been implemented by using an oversize continuous thumbwheel (see Figure 3-9). Since it is one of the primary controls, it is located on the main control console directly in front of the engineer and placed for right-handed operation. This control can be operated using either the fingertips or the heel and palm of the hand. The wheel's surface has tactile coding to indicate the power, idle or dynamic brake sections of the wheel. The idle portion of the wheel is smooth. The dynamic brake portion has raised ridges while the throttle portion has engraved grooves. In the case of both throttle and dynamic braking, higher settings will have the tactile coding closer together. In addition, the color green appears under the window when motoring, and blue appears when dynamic brake is employed. This provides an additional cue to the engineer because this color coding is the same as on the power force indicator.

The engineer actuates the motoring portion of the control by rolling the wheel forward from the idle position to motor. This section of the control has a lighted, marked position indication visible in the indicator window for the purpose of control position feedback, but the control is continuous in its operation. The reasoning behind having a continuous throttle instead of a detent control is that a more precise operation is available. A specific instance where a continuous throttle would appear to be advantageous is in the case of pulling a heavy train uphill, where maximum tractive effort could be maintained without slipping the drive wheels by finding the control position that best achieves this. Also, in the case of maintaining a given speed,it may be that one detented throttle notch is too fast and the one below it too slow, whereas a continuous throttle control has an infinite number of positions.

The engineer actuates the dynamic braking portion of this control by depressing the interlock button to the left of the control and rolling the wheel back first to the set up position. Eight dynamic brake positions are then indicated for the engineman to use by rolling the wheel further to the rear to increase dynamic braking. In braking this way, the vehicle will tend to run faster when the control is rolled forward and slower when rolled rearward, no matter which section of the wheel is being used.

The requirements for having both dynamic brake and throttle on the same control are that (1) both functions govern the behavior of the traction motors and cannot be used simultaneously, (2) these controls should be designed so that the engineman will not confuse increasing throttle with increasing dynamic brake (or vice versa) and (3) space could be conserved and simplicity of design maintained by putting two functions on the same control.

The above design was a result of an iterative process in which a number of alternatives were evaluated. The main alternative candidates were lever, slide and oversized rotary knob. The lever and slide had one main drawback in that the combination of motoring and dynamic brake on the same control made the control throws very small for each function and we felt that precise settings would be difficult to make. Both the knob and the thumbwheel approach offered a 180-degree control throw for each function, this gave considerably more latitude to the designer in laying out the control positions. However, the oversized thumbwheel seemed to offer the best qualities of a long control throw while making fine settings and adjustments possible.

3.5.6.2.4 Manual Sand

The manual sander control is a push-to-activate control. Depressing the button lights the switch, and sand is applied to selected traction wheels. Depressing the sander while sanding causes the light to go out and the sanding to cease.

3.5.6.2.5 Stop All Engines

The Stop All Engines function is also a push-button switch which has a plastic guard over it to prevent accidental activation. Depressing this momentary switch and holding it causes all engines in the consist to shut down. Releasing the switch returns it to normal and the guard snaps closed over it. It should be noted that in an electric locomotive as opposed to a diesel electric, this switch would be replaced by one that lowered all pantographs.

3.5.6.2.6 Direction Lever

The direction lever is a three-position lever - locked toggle switch as opposed to the rather hefty lever found in present day cabs. There are three functions that this switch must accommodate: forward, aft and neutral. To change switch positions, the toggle switch must be picked up out of its locked position and moved to the next selection indicated by the arrows. Note that this two-action task is required to prevent inadvertent movement of the reverser while the train is moving. An additional electrical interlock to prevent this is also recommended from a human engineering standpoint.

3.5.6.2.7 Console Lock

Since the levers in this cab are not removable, to secure the locomotive, a key operated switch has been added to the console. With the switch in the "OFF" position, the engine will be idling but no controls will be effective. When the key is turned to the "OPERATE" position, the controls become effective and the key is not removable. In the "OFF" position the key can be removed from the lock. It would be desirable to issue each engineer a key as part of his standard equipment along with his rule book and have him be solely responsible for it. A key that is locomotive owned places the responsibility for it nowhere. Maintenance personnel would be required to establish a separate procedure for access to keys.

3.5.6.2.8 Bell

The train bell activator push-pull control is located in a "well". The space between the control and the side of the panel is large enough to permit griping the controls with the fingers and pulling up. This starts the train bell ringing and it will remain ringing until the control is pushed back down in the well. There is also a provision for the horn switch to auotmatically activate the train bell which then must be turned off manually.

3.5.6.2.9 Emergency Stop

The emergency stop push button is located to the right of the throttle. The emergency brake function has been removed from the train brake where it is located in production cabs. It is a push-button switch. This should cut down on the time to activate, which is presently required as the control passes through all the other brake positions for this very critical control. A push of the fingers or the heel of the hand will activate this switch. As noted, the brake "reset" function to recover from an emergency application is still a setting on the train brake and the lever must be raised and placed in this setting ensuring that the train brakes are released before the "reset" function begins.

3.5.6.3 Repeater Control Panel

As stated earlier the primary control functions have been located to maximize forward movement over the road during line haul operations. However, it is recognized that during a typical run, for example, the engineer and his crew may be required to deliver or pick up shorts and back into sidings. This requirement means that the locomotive will be operated in the reverse direction. To enable the engineer to accomplish this conveniently, a repeater control panel is provided as shown in Figure 3-11.

The repeater panel is located on the side wall in back of the engineer's chair and is used when the engineer is moving in the direction of the long hood. The panel folds and latches partially into the wall when not in use. Some of its bulk will extend outward from the wall; however, it is designed so as not to introduce a safety hazard because of the intrusion. When the engineer rotates his chair 180°, he can conveniently reach and operate these controls to propel his locomotive in the reverse direction.

The functions contained on the panel are as follows:

a. EMERGENCY BRAKE built to the same specifications as it is on the front panel.
b. DIRECTION LEVER in the form of a lever-lock toggle switch.
c. TRAIN BRAKE control as a slide switch with appropriate detents. It operates the brakes when pulled toward the engineer.
d. INDEPENDENT BRAKE control is done with push buttons. One for RELEASE and one for APPLY. The APPLY button will increase brake effort the longer it is held down.
e. SPEED CONTROL, another slide is continuous from IDLE through a position 8. On the right hand side of the box (facing aft) is a simple pring loaded HORN switch. The horn can be blown by pressing in the top of the switch. Modulation of the horn can be accomplishe- through the use of the switch.

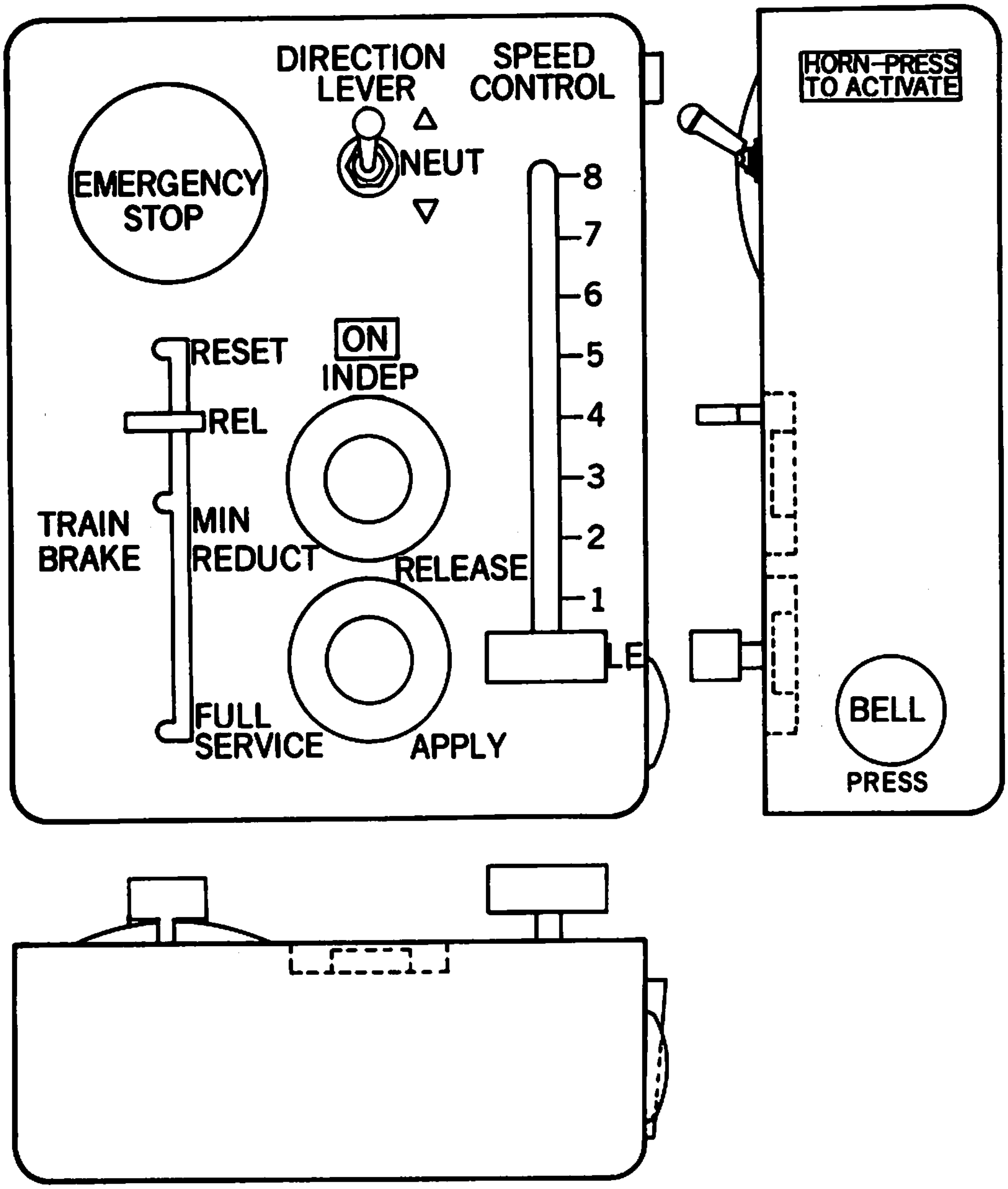


Figure 3–11. Repeater Control Panel

3.5.6.4 Secondary Display Panel

Annunciator Panel

The annunciator panel seen in Figure 3-12, is directly to the left of the primary display panel. Items located on this panel concern the presentation of train and locomotive systems performance. When the panel is not energized, the front face is black and legends on the annunciator will not be readable even under bright sunlight. In this way, it will not pose a distraction to the engineer. When appropriate legend is energized, it will become visible and appear either red, yellow or green, depending on whether the light is giving a warning, caution or advisory message. In context, a warning message signals a hazardous situation and the engineer must take immediate action to rectify the situation. Caution means a situation exists that the engineer should be aware of and attend to at the earliest possible time to avoid damaged equipment or lading. An advisory light advises the engineer of a condition that he should be aware of (status), but one that does not imply a malfunction or emergency and therefore does not require immediate action.

Warning annunciators are the Emergency Brake ON light located on the main panel described earlier, and an overspeed annunciator to warn the engineer that he is exceeding the maximum safe speed. The latter warning indicator may be linked to automatic train control (ATC) equipment so that a warning is given to the engineer before the ATC cuts locomotive power. Both lights have an illuminated red background and lack opaque lettering.

Caution indicators have an opaque background with yellow illuminated legends. The consist alarm light informs the engineer that one or more locomotives in the consist has incurred a malfunction and should receive attention. It was determined early in the design stage that more specific information than this about another locomotive would not be useful. No action can be taken unless the train is stopped and the fault is corrected or isolated, so no separate indication is given for specific malfunction in other locomotives. The legends and action to be taken by the engineer for each light in the annunciator panel appears in Table 3.2

TABLE 3-2. ENGINEERING WARNING ANNUNCIATOR LEGEND LISTING

Legend	Color	Meaning
Consist Alarm	Yellow	Correct fault or isolate locomotive in consist.
Traction Motor Hot	Yellow	Traction motor is overheating - damage will occur if throttle is not reduced.
Wheel Slip	Yellow	Wheels are slipping - tractive effort must be reduced, or sanding initiated.
Overspeed	Red	Maximum safe speed has been exceeded - take action to reduce speed or penalty brake will apply.
Excitation Limit Fail	Yellow	Generator excitation protection system has failed - cut tractive effort.
PCS Open	Yellow	Pneumatic control switch has opened - apply brake handle to "suppression" followed by "reset" on train brake control.
Crankcase Oil Press Hi	Yellow	Oil pan pressure in engine is high.
Engine Hot	Yellow	Engine has overheated.
No Battery Charge	Yellow	Battery charging system has failed.
Oil Level Low	Yellow	Lube oil system does not have sufficient oil.
Blower Failure	Yellow	Equipment blower has failed.
Air Filter Clogged	Yellow*	Engine air filter is not longer serviceable.
Turbo Air Press Low	Yellow*	Turbo charger is not providing enough boost for proper power development.

TABLE 3-2. (CONTINUED)

Legend	Color	Meaning
Fuel Press Low	Yellow	Insufficient engine fuel pressure condition exists.
Oil Press Low	Yellow	Insufficient oil pressure exists for safe operation.
Oil Filter Clogged	Yellow*	Lube oil filter is clogged and is being bypassed.
Fuel Filter Clogged	Yellow*	Fuel filter is no longer serviceable.
Turbo Oil Pump Fail	Yellow	Pump supplying oil to turbo-charger has failed.
Water Level Low	Yellow	Engine coolant level is low.
Hand Brake	Green	Hand brake is applied.

*These annunciators will be behind a maintenance advisory cover for use by maintenance personnel.

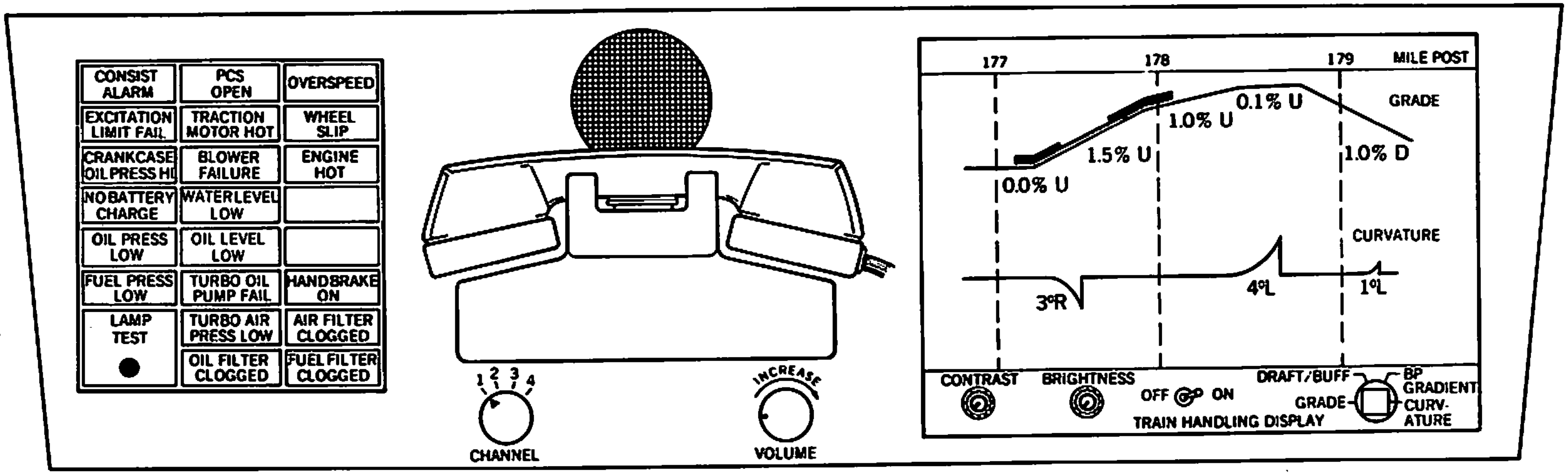


Figure 3–12. Secondary Display Panel

The above list of annunciator lights was derived from a composite of the engineering philosophies of G.E. and EMD, and a review of the operational requirements of the engineer. Also, comments on warning lights from the Railway Fuel and Operating Officers Association's "Manifest" were taken into account. Only indication of malfunctions which require action on the part of the engineer are presented. Exact specifications on actions taken in each case would be dictated by the locomotive manufacturers and the operating properties. A lamp test button is provided on the annunciator panel to assure that all annunciators are in working order prior to commencing a trip.

3.5.6.5 Train Handling Display

From the functional analysis, as has been stated, it was readily determined that the engineer must visualize a number of factors concerning train length, makeup and performance, as well as the dynamics that take place between these factors and track structure. An informal survey of the literature revealed that the industry had developed at least two devices to present these variables to engineers: the Train Handling Indicator and Train Handling Analyzer. The basic display is four mile section of the track ahead that is pre-programmed to show significant events such as grades, curvature, the location of the train and certain train handling and locomotive parameters. However, from a functional standpoint these devices were judged deficient for two reasons. First, because of their pre-programmed nature, the engineer when relying on these devices is in essence driving a theoretical train. This is true because routine line haul freight consists are not now instrumented to record and display train parameters in real time. As an extreme example, a train could literally break in two without affecting the displays. Secondly, the engineer must continually update these devices by inserting mile post numbers into them. This could be misleading and perhaps result in improper train handling if the engineer failed to insert a mile post number, or accidentally inserted the wrong one.

It is strongly recommended that train handling sensors and appropriate displays be developed that are based on real train measurements, rather than a mathematical model even if in the operating environment it is impractical to sense more than a few actual data points. A second recommended feature is that the device selected not require periodic update by the engineer. A system is envisioned where train and track information is entered once at the beginning of a run, either manually or preferably by data link to the locomotive computer. It is also extremely desirable from the human engineering standpoint to provide an information display. The display should present the particular batch of parameters he is interested in at any given moment. It is the opinion of the study team that this concept if implemented can make a more significant contribution to the resolution of present train handling problems than any other device examined during the study.

As an illustrative example of how this concept might work, assuming that reliable sensing devices and techniques are developed, the following analysis is presented for the recommended design.

A CRT medium was chosen for this display because of the ability to show a changing track-train situation in real time, and its flexibility in showing graphical types of displays. The display as shown in Figure 3-12 is a 7-inch high and 10-inch wide cathode ray tube with the following control capability:

a. Contrast
b. Brightness
c. Display Mode

The display mode selector is a four-position rotary switch which permits the engineer to select any of the following presentations.

a. Track Grade
b. Draft/Buff Condition
c. BP Gradient
d. Track Curvature

Some options are available to the engineers; for example, he can edit the display to show grade and draft/buff only, grade and BP gradient only, or grade and curvature only. The grade display shows a profile of the track under the train, labels indicating the severity of the grade and mile posts.

3.5.6.5.1 Grade

A representation of track approximately 1.5 miles ahead of the train is shown. This resolution is not meant to be an optimum value, but rather useful for illustrative purposes. The optimum resolution for this display should be derived from a functional test of the equipment in a simulated or real world environment. Currently, a four-mile section of track is displayed for the engineer on experimental versions of the Train Handling Indicator and Train Handling Analyzer. A long enough section of track should be shown so that the engineer can adequately plan his strategy and the display should have the greatest resolution possible so that details in grade changes will not be lost. Each grade change shown on the display is labeled with the percent grade and identified with "U" for upgrade and "D" for downgrade.

3.5.6.5.2 Draft/Buff

The next control position is that of the draft/buff condition of the train slack. It has been known for quite some time that proper management of train slack is one of the most critical aspects of train handling. The display provided here indicates which portion of the train is either in draft, neutral, or in buff, and the amount of drawbar force in each case. In this way, run-ins and run-outs can be predicted, and hopefully controlled, and the drawbar force can be managed to avoid excessive longitudinal shocks. In addition, by noting grade, curvature, and drawbar force, lateral forces on tract structure can be monitored and also controlled. As mentioned earlier, the Power/Drawbar Force indicator should have an input to preclude building up excessive lateral forces, and progress in this effort can effectively be monitored on this display with adjustments to control inputs made as necessary. Dotted lines across the display are provided to mark the maximum permissible draft and buff forces as well as to mark the neutral nodes.

The next presentation that may be selected is that of BPP gradient. This display contains a scale on the left from 0 to 110 psi, with the 0 to 50 psi compressed. A line representing the pressure gradient is directly beneath the representation of the train on the track as described above. As a brake pipe reduction is made, the line will move from the head end and will "snake" toward the rear as the BPP equalizes. This gradient will give a good indication of the braking action on the train and its relationship to the track and mileposts. It is possible that with this information available that some savings in fuel consumption, brake shoe wear, and equipment life can be realized because direct information on train dynamics will enable the engineer to spend less time pulling against the braking action in the case of stretch braking.

3.5.6.5.3 Curvature

The grade and curvature displays are juxtaposed. Curvature is shown in percent just under the track profile. This was done so that both variables of track structure can be easily compared and related to each other by the engineer. This was judged to be a reasonable way to depict a three dimensional situation on a two dimensional display. The grade display also presents train length and position along the grade as well as a general representation of train mass distribution and the engineer can quite easily determine the grade and curvature under any given segment of the train.

3.5.6.5.4 Locomotive Horn

The locomotive horn is a foot pedal located on the foot rest under the engineer's console. The horn is operated with the left foot and can be modulated.

a. Brake Pipe Feed Valve
The brake pipe feed valve is located on the outside wall of the engineer's console, to his left.

b. Radio
The radio handset for communications with the caboose crew and wayside is located within easy reach to the engineer's left next to the train handling display.

3.5.7 Auxiliary and Remote Consist Control Panel

An overhead panel, shown in Figure 3-13, was selected for the placement of the auxiliary and remote consist controls. The usable overhead panel dimensions are 30 inches long and 15 inches wide for a total of 450 square inches of space on which to locate and group the controls. The console is positioned so that a 5th percentile man from the general population can reach the controls on the panel from his seated position. It also makes it easy for the engineer to get in or out of his seat.

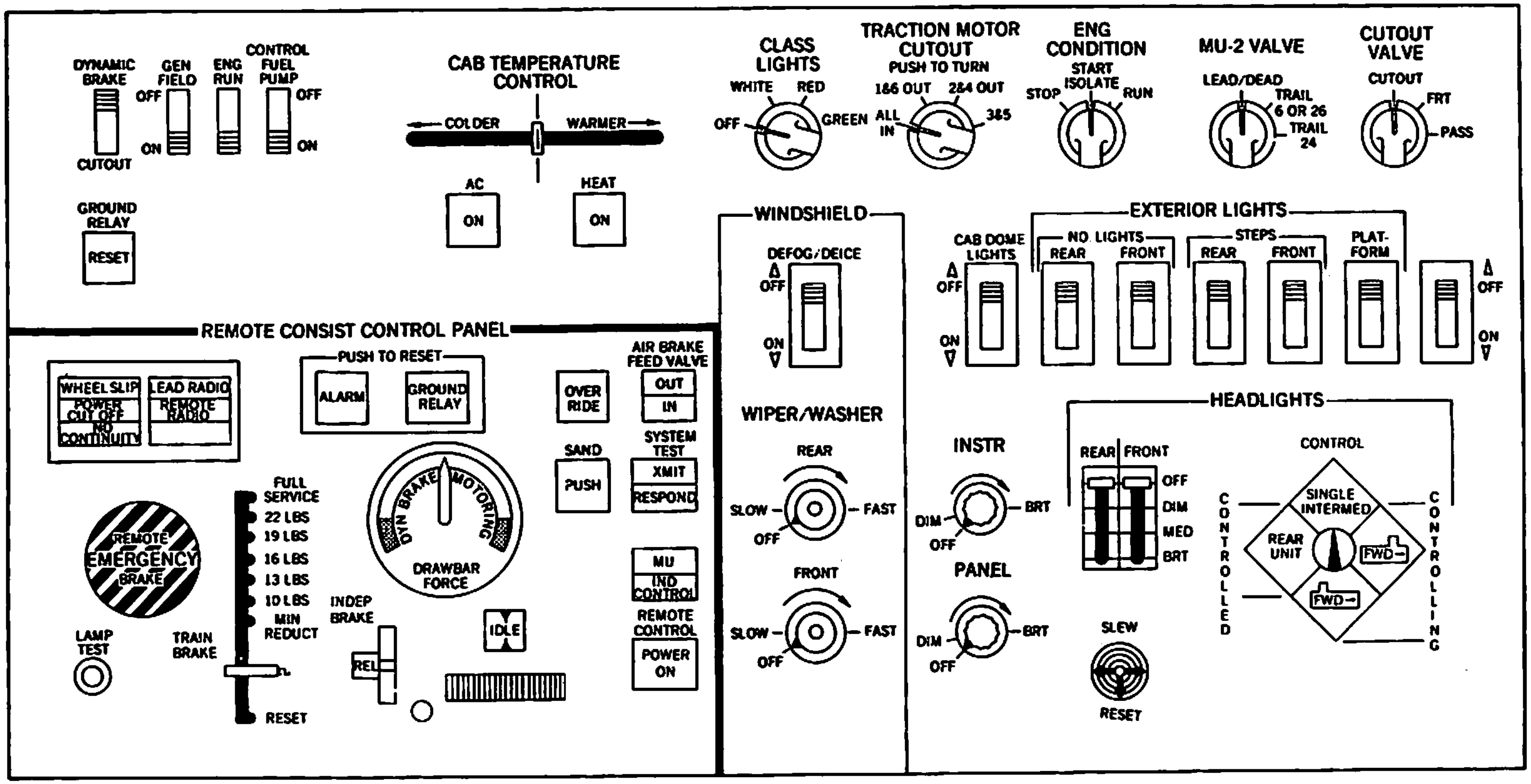


Figure 3–13. Overhead Auxiliary Control Panel

The layout of the overhead panel was based on the following criteria. The principal one is that, since frequency of use is not a requirement, functional grouping outside of the primary reach area is important. Discrete rotary selector switches were chosen to implement functions requiring more than two positions. It should be noted that these functions are used primarily during train set up and therefore the tasks are usually performed during lead cab inspection by the crew. The lighting controls are grouped together by function and each one is independent. This feature is desirable because if all lights were wired to a single master light switch, inadvertent actuation would extinguish all lights resulting in a potential hazard. The sliding button switches are used for their compactness and simplicity. It should be noted that many of the controls appearing on the overhead auxiliary panel are located on the rear wall of present day cabs. The auxiliary controls are discussed counterclockwise as follows:

1. Dynamic Brake/Cutout
The dynamic brake cutout switch is used to isolate the controlling locomotive's dynamic brakes from those of the rest of the consist.

2. Ground Relay/Reset
This push button switch will light up when a high voltage ground occurs or five main generator diodes in a parallel group fail. After ten seconds the engineer can attempt a reset by depressing the button. When the light extinguishes, it indicates that the protective relay is reset.

3. Generator Field
This two position switch when moved to ON turns on the generator field in the main generator.

4. Engine Run
The engine run switch couples the engine to the throttle control.

5. Control Fuel Pump
The control fuel pump switch turns the fuel pump on and off.

6. Cab Temperature Control
As shown, the cab temperature control permits the engineer to select air conditioning or heating via a pair of push button switches. A slider control allows him to adjust and maintain the temperature of his cab. The sliding switch was selected because the range of movement gives the capability for fine adjustments and it can be positioned by feel. The slide detents in the center or average setting provide additional tactile feedback. However, it is recognized that there are occasions when the engineer must frequently open his side window and sometimes operate the locomotive with the window open for long periods of time. To maintain a satisfactory cab environment, provide thermostat that senses the cab ambient temperature and causes the heating or air conditioning to maintain temperature at a preset value should be used.

7. Class Lights
The class lights are selectable with a four position rotary switch.

8. Traction Motor Cutout
The traction motor cutout selector is a four position push to turn rotary switch. It is push to turn because the associated circuits must be disconnected prior to changing positions. Pushing disconnects the circuits. The first position, ALL IN, when selected, supplies electrical power to all traction motors. The second position when selected disconnects the number 1 and 7 traction motors. The third position when selected disconnects the number 2 and 4 motors, and similarly the fourth position disconnects the number 3 and 5 motors. The cutout function is desirable for two reasons. First, it allows the engineer to cut out selected traction motors in the event of a malfunction and secondly, it allows him to cut out traction motors during motoring or dynamic braking to avoid excessive draw bar forces.

9. Engine Condition
The engine condition is a three position rotary control with the following functions. Selecting the stop position shuts off the engine. Selecting the start isolate position starts the engine and permits the locomotive to idle but not respond to any control commands. Selecting the run position permits the locomotive to respond to input commands from the engineer.

10. MU-2 valve- is a three position rotary switch that permits the following functions.

    a. Lead/Dead position is used when the locomotive is operated singly or when it is the lead unit of a multiple-unit consist. This position is also used when the locomotive is being hauled "dead-in-train".

    b. Trail 6 or 26 position is used when the locomotive is a trailing unit being lead by a locomotive hauling 6 SL or 26 L brake equipment.

    c. Trail 24 position is used when the locomotive is a trailing unit being lead by a locomotive having 24 RL brake equipment so that compatibility is assured between leading and trailing units.

11. Cutout Valve

    a. Cutout position is used when the locomotive is a trailing unit and the air brake equipment is receiving command inputs from another locomotive. It is also used to cut out the pressure maintaining equipment when making train brake tests to check brake system leakage.

    b. FRT position denotes the position to be sed in freight operation.

    c. PASS position allows the engineman to make a graduated release of the train brakes when in passenger service.

12. Lighting
The exterior lights are controlled by five ON/OFF sliding switches. They include number lights, both front and rear, step lights, both front and rear, and platform light. To the left of this series of switches is an identical switch for the cab dome lights. The switch to the far right is a spare. Headlight control is achieved with four controls; a four-position rotary selector for configuration management, two four position dimming controls for rear and front headlights and a headlight slew switch which permits the engineer to slew the headlight right or left.

13. Headlight Controls
The main setup control, as shown on the panel drawing, is easily identified by the diamond-shaped placard. This selector is placed in one of four positions depending on the role of the locomotive in the consist. If the locomotive is operating as a single unit or is one of the intermediate units in a consist, the selector is placed in the Single/ Intermed position. If the locomotive is a rear unit in the consist, the selector is placed in the Rear Unit position. If the locomotive is a lead unit controlling a consist with the short hood forward, the selector is placed in the position marked with the picture of the locomotive with the short hood forward.

Likewise, if the locomotive is a lead unit controlling a consist with the long hood forward, the selector is placed in the position marked with the picture of the locomotive with the long hood forward. The latter two positions are bracketed by the word Controlling to indicate that one of these two positions is chosen when the unit is controlling a consist. The Rear Unit position is bracketed by the legend Controlled.

Headlight intensity is selected by actuating the appropriate switch (FRONT or REAR) in the OFF, DIM, MED, or BRT (bright) position. In this way any combination of lighting setup is possible. Slide switches are used because in their side by side placement a feel comparison can be made to determine the relative location of the front or rear headlight control. The slew switch is available for the engineman to swing one headlight to the right or left for better visibility around curves or to inspect the right of way for obstructions. Use of the control is accomplished by pushing the "coolie hat" shaped switch either left or right depending on the desired placement of the headlight. Releasing the switch will lock the headlight into position. When the steerable headlight is needed in its normal straight ahead orientation, the switch is pushed toward the position marked RESET and the headlight will return to its normal position.

Adjacent to the headlight controls two rotary dimmer switches are located. These controls permit the engineer to vary the brightness of instruments on the panel and legend illumination continuously from Dim to Bright.

To the left of the brightness controls, arranged from top to bottom, is an on/off defog/deice control, and two windshield wiper/washer three-position rotary controls for front and rear windshields that allow the engineer to select the speed of the sweep. These rotary controls, it should be noted, require little force and allow for precise adjustment. The sliding pushbuttons are selected for their compactness and simplicity. When these switches are on, a white background is visible to the operator. These switches are easily operable, and do not require lighted legends to indicate their status, and thus will not interfere with the engineer's night vision.

The selector switches for CLASS LIGHTS, TRACTION MOTOR CUTOUT, ENGINE CONDITION, MU-2 VALVE and CUTOUT VALVE were chosen for the following reasons: (1) The controls are used infrequently in most instances only once per run, (2) The set position is built in so no other indication is necessary, (3) It takes a sure, deliberate movement to position them, (4) They are easy to locate by touch.

3.5.8 Remote Consist Control Panel

The remote consist control panel is located in the lower left corner of the auxiliary control panel. This location is easy to reach for the engineer. Early in the design development phase, some thought was given to integrating the remote consist control functions with the primary locomotive controls, because of the similarity of function. However, this approach was rejected. First, some carriers do not employ remote controlled locomotives and would, if the developed cab was found suitable for production, penalize these properties with unwanted features. Second, since locomotives are often demoted in service as they become older, it was determined that a modular approach would be beneficial because the module could be easily removed if a locomotive was no longer employed as a radio controlled remote unit. Third, although the functions are optional, it still remained to provide a coherent blend into the remaining crew systems and not permit the module to be added on located arbitrarily at the crew station. Figure 3-13 shows the arrangement of the functions on this panel and they are discussed below.

1. Train Brake
The train brake is a slide control with notched settings for appropriate brake pressure control. It is relatively small because space is at a premium on this panel. Control positions are reset, minimum reduction and full service with three pound

increments intermediate between them. Preliminary analysis revealed that these three pound increments provide the engineer with sufficient capability to manage the remote locomotive. The remote consist train brake does not have a suppression section because this function can be accomplished elsewhere.

2. Speed Controller
The speed controller is a handwheel. When turned to the right, speed will increase continuously from idle to the highest setting and the color under the wheel is blue corresponding to the blue region on the drawbar force indicator. When the control wheel is in idle position, dynamic braking cannot be achieved unless the adjacent pushbutton interlock is depressed. When the button is pressed, the wheel can be moved to the left (set up position) indicated in the window. Once in the setup position, the dynamic brake may be positioned continuously to the desired setting. A blue band appears in the window, corresponding to the blue band on the draw bar force indicator.

3. Override Switch
The override pushbutton switch, when actuated, keeps the remote consist in power or dynamic braking, whenever radio communications between the lead and remote locomotive is interrupted.

4. Sand
The sand pushbutton switch is used to manually apply sand in the event that the automatic sander in the remote locomotive fails. When the automatic system fails, the switch lights which inform the engineer to push when he wishes to apply sand to the track under the remote locomotive. He has the option, however, to push the switch anytime he requires sand in the remote locomotive.

5. Air Brake Feed Valve
The air brake feed valve essentially performs a check function. If a brake pipe pressure check is to be made, the engineer must punch the air brake feed valve out in addition to shutting off the feed valve in the operating console. This will give a better indication of brake pipe leakage than if the remote control units were still supplying brake pipe air into the brake line. After the test is

complete, the operator must actuate the switch again to put the remote consist air brake feed valve back on the line. When the CUT OFF valve is closed on the lead engine to prevent the brake pipe from recharging, it is also necessary to cut out the remote consist AIR BRAKE FEED VALVE. When the AIR BRAKE FEED VALVE is cut out the OUT portion of the switch is lighted. When it is cut back in, the IN portion of the switch is lighted.

6. Independent Brake
The remote consist independent brake is shown to the right of the speed controller. This is a thumbwheel and indicator in which is shown the brake setting of the remote locomotive(s).

7. Emergency Brake
In an emergency requiring immediate stoppage, hitting this button with the palm or heel of the hand will activate the remote locomotive's train brake which, in turn, will then initiate braking forward and backward along the consist.

8. Lamp Test
The lamp test button when pushed will light all lighted instruments so the engineer can assure himself that all lights are fit and functional.

9. Caution
The caution annunciator panel is located just above the emergency brake. Each bit of information displayed here is vital to train operation with remote locomotives. When an indicator lights, the operator must take the appropriate action. The lights are amber and indicate the following conditions: wheelslip in the remote locomotive(s), requiring the engineer to either reduce the power or apply sand or both. Power cut off indicates that power is lost in the remote consist. In this case the engineer has several options. He can continue the mission under reduced power, he can take the train to its destination in several sections, call for a replacement or ask for a maintenance crew. Of course, the option selected would depend on the local situation and the dispatcher.

10. Drawbar Force Indicator
Above and slightly to the left of the speed control wheel is the drawbar force indicator. This instrument will indicate the amount of drawbar force the remote consist is exerting when the speed control is being used and the train is being stretched. It will also indicate the amount of drawbar force when the train is in DYNAMIC BRAKE and being bunched. This indicator is identical to the indicator on the main instrument panel.

11. Alarm and Ground Relay
Above the DRAWBAR FORCE indicator are two push button switches that require reset. These are ALARM and GROUND RELAY. If either of the switches lights up, the operator depresses the push button for two seconds, releases and looks to see that the light goes out. If it does, the reset has been accomplished. If it does not go out after a short period of time, the reset is tried again. After the third attempt, the train will be stopped and the cause of the reset found before proceeding any further.

12. System Test Switch
The system test switch is used to test the continuity of the remote consist panel signals to the remote consist. When activated the XMIT side of the pushbutton lights up. If continuity is present, the XMIT portion will go out and the RESPOND half of the switch will light up. This will remain on for ten seconds, then the RESPOND portion will extinguish and the test is complete.

13. MU/IND CONTROL
The next pushbutton switch provides a choice of remote consist control. If the switch is set on MU the remote consist will respond in the same manner as the lead consist; if set on IND CONTROL, the engineer can then operate the remote consist speed control, dynamic brakes, train brakes and independent brakes at different settings using the controls on the remote consist panel.

14. Power On
A power on pushbutton switch that, when activated, will supply electrical power to the remote consist control panel.

3.5.9 Engineer Console Internal Vision and Reach

It was necessary, once the controls and displays were located and defined, to verify that their placement was within the fifth percentile engineer's reach and vision envelope. To systematically evaluate the placement of controls and displays and to troubleshoot the design, a computer program was used. The design eye point and the location of each control and display, in cab coordinates, were inputted to a computer. The program outputs are shown in Tables 3-2 through 3-5.

Table 3-2 is a print out of panel points for the main to right: control name; cab coordinates in using the same type of coordinates used in the engineman vision plots discussed earlier; horizontal deflection angle; vertical deflection angle; line of sight angle of incidence and its tangent; visual and reach distances. The visual angles are especially useful during the design phase in providing details concerning instrument bezel depths, potential problems and dimensions for lettering and numerals to minimize the reading time at each display.

The last three columns in the table are reach distances for the right hand, left hand and right hand overhead reach respectively. The value at the top of the vision column indicates the 28-inch maximum allowable viewing distance and the values at the head of the last three columns is maximum allowable reach distances from theoretical shoulder points.

An asterisk appearing next to a number indicates that the allowable value is exceeded. Three violations are shown under vision. However, these violations are not to be judged significant if it is recognized that the design eye point is fixed for analytical purposes. Practically, the engineer has a latitude of head and eye movement. By the same token, under reach, three items are observed to violate the criteria. However, these too are not judged significant because again, in practice, the engineer has a degree of torso and shoulder movement around the fixed analytical point.

Table 3-3 shows a similar print out for the main display panel. All items on the panel fall within the 28-inch viewing requirement. Reach distance to this panel is not of primary concern, but the cab signal acknowledgement button and elapsed time indicator can be easily reached when the engineer leans slightly forward for a distance of less than one inch. This should not pose any operational problems.

TABLE 3-3. INTERNAL VISION AND REACH ANALYSIS - MAIN CONTROL PANEL

PT. NAME	STATION	BUT LINE	WATER	HOR DEFL	VERT DEF	ANGLE	TAN	VISION 28.00	REACH 25.60	25.60	25.60
TRBRKFSP	-6.84	35.19	29.51	-48.81	-68.96	30.65	0.5926	28.92***	26.28***	21.55	27.69***
TRBRKREL	-11.52	35.15	33.56	-34.26	-58.70	22.03	0.4047	26.84	26.37***	21.62	27.48***
SAND	-11.30	31.65	33.37	-45.13	-55.31	27.82	0.5277	28.13***	28.48***	21.96	29.53***
INDBRKFA	-7.37	40.68	29.96	-17.46	-73.77	25.80	0.4835	27.64	23.49	22.02	25.02
INDBRKREL	-10.54	40.66	32.71	-12.53	-65.58	17.73	0.3198	26.12	23.50	22.01	24.81
STOP ENG	-11.98	43.65	33.96	3.09	-61.98	12.99	0.2307	25.54	22.70	23.11	23.95
THROTTLE	-9.11	46.87	31.47	23.02	-68.43	22.41	0.4124	26.91	21.62	24.07	23.14
DIRECTN	-12.21	48.74	34.15	25.20	-58.88	17.59	0.3170	26.10	21.83	25.36	23.10
BELL	-7.22	50.38	29.83	45.65	-68.84	29.53	0.5664	28.60***	21.48	25.59***	23.15
EMERSTOP	-9.71	50.36	31.99	37.17	-63.56	24.62	0.4582	27.37	21.37	25.89***	22.87
LOCK	-11.75	51.25	33.76	35.06	-57.73	22.29	0.4100	26.89	21.69	26.64***	23.01

END OF DATA FOR PANEL,MAINCONT

TABLE 3-3a. INTERNAL VISION AND REACH ANALYSIS - MAIN DISPLAY PANEL

PT. NAME	STATION	BUT LINE	WATER	HOR DEFL	VERT DEF	ANGLE	TAN	VISION 28.00	REACH 25.60	25.60	25.60
MAINRESP	-18.88	29.00	41.58	-36.56	-32.40	33.69	0.6666	27.84	32.51***	25.51	32.93***
AIR FLOW	-20.11	29.00	44.54	-34.85	-26.02	31.84	0.6211	27.27	33.03***	26.17***	33.27***
BPEQRPRS	-19.43	32.30	42.92	-28.84	-31.47	27.07	0.5110	26.01	30.66***	25.10	31.02***
BRKCYLPR	-20.11	35.40	44.54	-20.70	-29.09	19.69	0.3579	24.60	29.32***	25.28	29.59***
EMERBRKL	-19.22	35.40	42.42	-21.57	-34.27	22.18	0.4078	25.01	28.86***	24.75	29.28***
BPVENTLT	-19.03	35.40	41.95	-21.77	-35.37	22.83	0.4210	25.13	28.79***	24.66	29.24***
SPEEDO	-19.34	39.90	42.69	-9.11	-35.18	14.86	0.2654	23.96	26.88***	25.15	27.31***
PWRDBFOR	-19.03	45.40	41.95	7.19	-37.17	15.82	0.2833	24.07	25.13	26.48***	25.65***
CAB SIGA	-20.11	45.40	44.54	6.81	-30.57	10.01	0.1764	23.52	25.74***	27.06***	26.05***
CAB SIGL	-20.42	45.40	45.28	6.70	-28.63	8.52	0.1499	23.42	25.97***	27.28***	26.22***
ET STOP	-20.45	49.90	45.37	18.64	-27.28	17.51	0.3155	24.29	25.55	29.20***	25.79***
ET	-19.99	49.90	44.26	19.04	-30.06	18.58	0.3362	24.44	25.20	28.90***	25.54
MILES	-19.38	49.90	42.78	19.60	-33.70	20.47	0.3732	24.72	24.83	28.58***	25.29
MPH	-18.92	49.90	41.68	20.04	-36.36	22.12	0.4066	25.00	24.62	28.39***	25.16

END OF DATA FOR PANEL,MAINDISP

TABLE 3-4. INTERNAL VISION AND REACH ANALYSIS - SECONDARY DISPLAY PANEL

PT. NAME	STATION	BUT LINE	WATER	HOR DEFL	VERT DEF	ANGLE	TAN	VISION 28.00	REACH 25.60	25.60	25.60
PHONE	-5.41	9.58	44.03	-80.80	-20.22	38.06	0.7829	36.08***	42.12***	28.38***	42.34***
CHANNEL	-2.62	9.19	39.73	-85.56	-26.31	41.33	0.8796	37.83***	42.48***	28.71***	42.89***
VOLUME	-5.82	13.03	39.73	-79.00	-28.78	35.36	0.7096	34.83***	39.53***	26.34***	39.98***
CRT	-11.20	17.47	42.66	-66.31	-26.40	24.12	0.4477	31.13***	36.88***	24.90	37.20***
CONTRAST	-7.93	15.43	39.91	-73.96	-30.03	30.99	0.6006	33.14***	37.91***	25.25	38.36***
BRIGHTNS	-9.27	17.04	39.91	-70.34	-31.03	27.99	0.5314	32.17***	36.93***	24.72	37.40***
ON / OFF	-10.36	18.35	39.91	-67.20	-31.81	25.48	0.4764	31.47***	36.21***	24.42	36.68***
SELECT	-12.60	21.04	39.91	-60.15	-33.22	20.20	0.3680	30.27***	34.94***	24.16	35.43***
ANNUNPN2	-17.24	24.09	43.57	-47.64	-26.80	7.73	0.1357	28.67***	34.56***	25.42	34.84***

END OF DATA FOR PANEL,SEC DISP

TABLE 3-5. INTERNAL VISION AND REACH ANALYSIS - OVERHEAD AUXILIARY CONTROL PANEL (SHEET 1 OF 2)

PT. NAME	STATION	BUT LINE	WATER	HOR DEFL	VERT DEF	ANGLE	TAN	VISION 28.00	REACH 25.60	25.60	25.60
LAMPTEST	-10.24	28.60	64.00	-54.58	22.99	60.77	1.7873	19.19	31.19***	23.57	30.18***
EMER BRK	-7.98	29.00	64.45	-60.30	26.26	58.57	1.6362	17.97	30.12***	22.39	29.05***
ANNUNPNL	-5.04	29.60	65.04	-69.37	30.82	55.80	1.4714	16.67	28.90***	21.13	27.73***
GRUKES L	-2.20	28.90	65.62	-81.13	32.57	56.40	1.5050	16.93	28.91***	20.66	27.70***
DYNBRKCU	0.35	28.90	66.13	-91.41	34.33	56.72	1.5235	17.08	28.72***	20.39	27.46***
GENFLOSW	0.35	30.30	66.13	-91.57	37.16	53.99	1.3761	15.94	27.69***	19.96	26.39***
ENGRUNSW	0.35	31.30	66.13	-91.70	39.45	51.81	1.2712	15.16	26.98***	19.71	25.64***
FUELPUMP	0.35	32.30	66.13	-91.86	41.97	49.40	1.1666	14.40	26.29***	19.51	24.91
TRBRKREL	-10.14	31.50	64.02	-48.59	26.11	56.71	1.5231	17.08	29.22***	22.81	28.13***
TRBRKFLS	-6.81	31.50	64.69	-59.37	31.49	53.28	1.3404	15.67	28.04***	21.28	26.86***
ALARMRES	-4.85	33.40	65.08	-63.21	38.59	47.07	1.0750	13.76	26.27***	20.29	24.97
GRRFLRIM	-4.85	35.50	65.08	-57.12	43.86	40.83	0.8641	12.39	24.97	20.15	23.61
OVERRIDE	-4.85	38.30	65.08	-44.11	51.81	30.89	0.5982	10.92	23.43	20.31	21.97
FEEDVALV	-4.85	40.00	65.08	-31.75	56.41	24.56	0.4569	10.30	22.61	20.60	21.09
INDBRKCU	-10.04	34.40	64.03	-40.57	29.68	51.99	1.2794	15.22	27.40***	22.39	26.24***
GB FORCE	-7.20	35.50	64.61	-46.17	37.95	44.70	0.9896	13.18	25.67***	21.01	24.39
THROTTLE	-10.53	36.70	63.94	-30.88	31.21	49.23	1.1556	14.35	26.36***	22.63	25.17
THINTLUK	-11.02	35.00	63.84	-35.57	28.31	52.72	1.3135	15.47	27.50***	22.90	26.36***
THINDICA	-9.36	36.70	64.17	-33.95	34.22	46.61	1.0579	13.64	25.84***	22.02	24.60
SAND	-6.51	38.20	64.75	-36.38	45.54	35.79	0.7210	11.55	23.98	20.88	22.59
SYSTEST	-6.51	40.00	64.75	-24.73	48.99	30.56	0.6000	10.93	23.13	21.17	21.68
MV/INDCO	-8.38	40.00	64.37	-19.70	41.50	37.92	0.7790	11.88	23.85	21.95	22.48
POWER	-10.04	40.00	64.03	-16.63	35.71	43.45	0.9473	12.91	24.59	22.75	23.29
AIR COND	-1.61	36.10	65.74	-76.84	52.50	36.38	0.7367	11.64	24.01	19.40	22.53
HEAT	-1.61	38.60	65.74	-69.87	63.09	25.18	0.4702	10.36	22.63	19.61	21.05
TEMPCUNT	-0.04	37.40	66.05	-69.54	59.62	32.17	0.6291	11.07	23.12	19.30	21.55
FRWSWIPE	-9.36	42.90	64.17	-0.61	39.35	39.25	0.8169	12.10	23.20	23.14	21.81
RRWSWIPE	-7.10	42.90	64.63	-0.81	48.85	29.75	0.5715	10.79	22.22	22.16	20.72
DEFOGICE	-3.57	42.90	65.34	-1.60	67.98	10.63	0.1876	9.54	21.11	21.04	19.45
CLASS	0.05	42.40	66.07	-95.07	86.40	12.25	0.2171	9.59	20.76	20.34	18.99
TMCUTOUT	0.05	45.50	66.07	91.22	75.36	18.67	0.3379	9.89	19.80	21.55	17.93

TABLE 3-5. INTERNAL VISION AND REACH ANALYSIS - OVERHEAD AUXILIARY CONTROL PANEL (SHEET 2 OF 2)

PANEL POINTS FOR(OHD PANE),CREWMAN(ENGINEER),PAGE 2

PT. NAME	STATION	BUT LINE	WATER	HOR DEFL	VERT DEF	ANGLE	TAN	VISION 28.00	REACH 25.60	25.60	25.60
ENG COND,	0.05,	48.40,	66.07,	90.57,	60.57,	31.48,	0.6124,	10.99	19.31	23.01	17.39
MUZVALVE,	0.05,	51.50,	66.07,	90.36,	48.39,	42.94,	0.9304,	12.80	19.26	24.85	17.34
CUTCUTVL,	0.05,	54.50,	66.07,	90.27,	39.77,	51.22,	1.2445,	14.96	19.68	26.85***,	17.81
DOME LIT,	-3.57,	46.40,	65.34,	43.57,	60.84,	22.21,	0.4083,	10.12	20.16	22.48	18.42
REARNDLT,	-3.57,	47.90,	65.34,	53.90,	55.55,	29.05,	0.5554,	10.72	19.93	23.22	18.16
FRONT ND,	-3.57,	49.50,	65.34,	61.20,	50.00,	35.69,	0.7184,	11.54	19.81	24.10	18.03
REARSTLT,	-3.57,	51.00,	65.34,	65.93,	45.25,	41.15,	0.8739,	12.45	19.81	24.99	18.03
FRONTSTL,	-3.57,	52.50,	65.34,	69.38,	41.05,	45.87,	1.0308,	13.46	19.92	25.93***,	18.15
PLATFORM,	-3.57,	54.00,	65.34,	72.00,	37.39,	49.92,	1.1886,	14.56	20.15	26.92***,	18.40
SPARE SW,	-3.57,	55.50,	65.34,	74.04,	34.21,	53.41,	1.3469,	15.72	20.48	27.96***,	18.76
PANELLTS,	-9.46,	46.20,	64.15,	18.70,	37.48,	41.84,	0.8952,	12.58	22.42	24.40	20.98
INSTRLTS,	-7.10,	46.20,	64.63,	24.25,	46.[illegible],	33.65,	0.6657,	11.26	21.36	23.43	19.79
REAR HL ,	-6.71,	48.70,	64.71,	40.34,	42.99,	38.87,	0.8059,	12.04	20.87	24.51	19.26
FRONT HL,	-6.71,	49.30,	64.71,	43.19,	41.72,	40.54,	0.8553,	12.33	20.84	24.84	19.22
SLEW ,	-10.24,	48.90,	64.00,	29.95,	32.39,	47.96,	1.1089,	13.99	22.50	26.02***,	21.08
HL SETUP,	-7.98,	53.10,	64.45,	51.67,	31.69,	51.73,	1.2677,	15.13	21.54	27.51***,	20.01

END OF DATA FOR PANEL,OHD PANE

Table 3-4, secondary display panel, reveals as expected that the communications system is outside the primary reach area by approximately three inches. However, anthropometric evaluation during soft mock up review, demonstrated that this location was also within easy reach. Table 3-5 indicates that all controls and displays on the overhead panel are within prescribed limits. It should also be noted that the overhead console is so located that is is not a hindrance to the 95th percentile operator and at the same time easily reachable by him.

The method employed and the resultant analysis provided quantitative design substantiation that all human engineering work station criteria were met in the recommended cab design.

3.5.10 Brakeman's Crew Station

The brakeman's crew station is located on the left hand side of the cab (see Figure 3-14). The brakeman is provided with a seat that is identical to that of the engineer and excellent visibility is provided from the left hand side of the cab. Directly in front of the seat is a console containing a writing and storage surface. Directly above the writing desk is a small display and control panel. At the left are two switches: one for local lighting (mounted either under the glare shield or as a recessed pencil beam light in the cab roof) and the other for local heating/air conditioning. To the right of these switches are a repeater speedometer and repeater cab signals located for the purpose of monitoring status of these variables.

To the lower right the emergency brake valve, communications handset, fire extinguisher and trash container are shown in Figure 3-2. It should be noted that these items are recessed into the front wall and secured to prevent them from becoming safety hazards. Provisions for an optional third seat, which is fixed, is shown in back of the brakeman's seat.

No attempt was made to assign the brakeman any functions other than to monitor speed and signals. The skills of brakemen do not include train handling, and this condition is not likely to change in a 10 to 15 year time span. Therefore, the brakeman's crew station contains no controls or displays related to train operation.

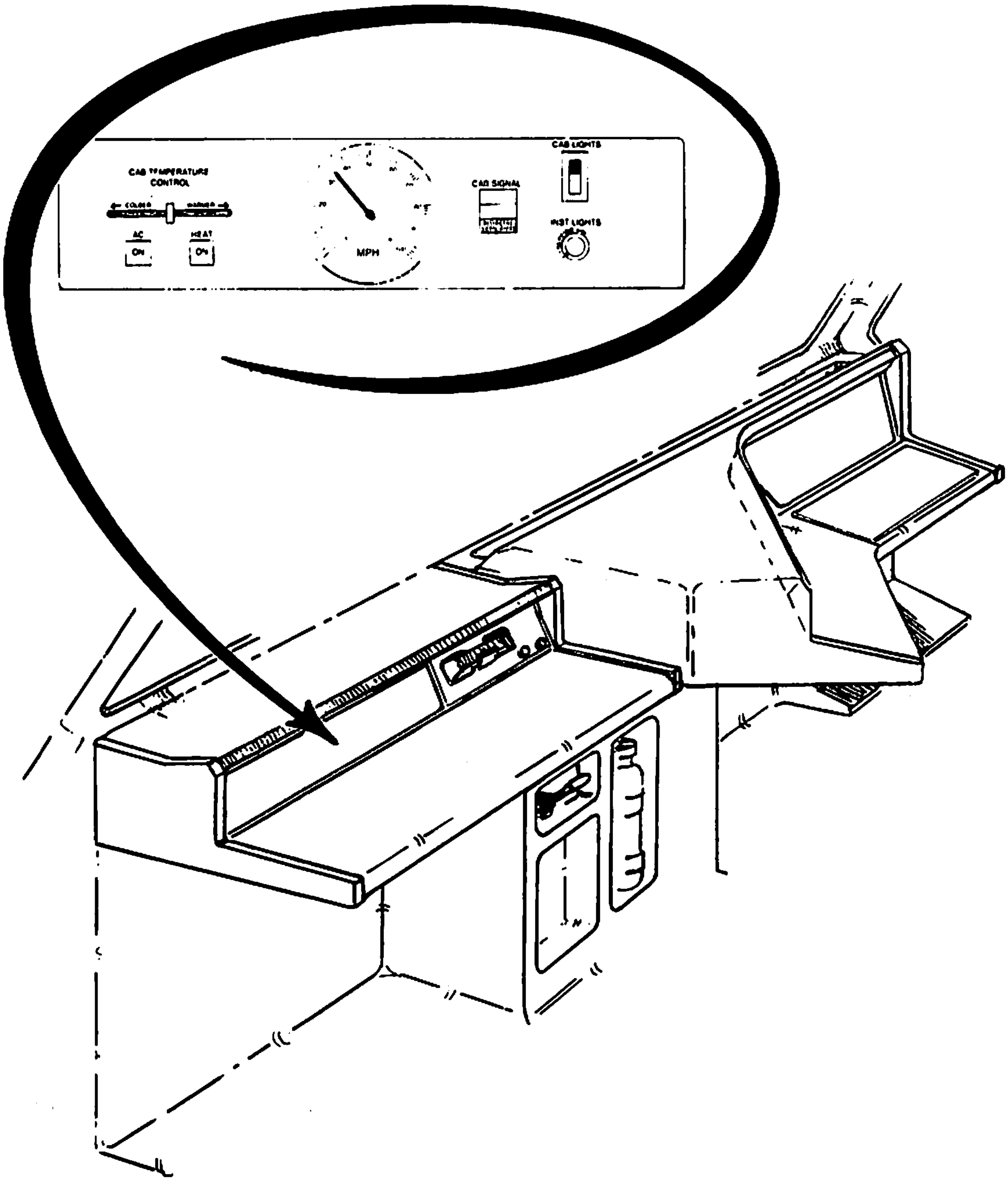


Figure 3–14. Brakeman's Crew Station

3.6 CAB INTERIOR

This section describes the general cab interior and appointments.

3.6.1 Ingress-Egress

Two doors are provided at the rear of the cab that are of a conventional hinged type opening to the outside. Door handles are of the recessed type with a non-rigid hand hold on the inside to facilitate door closing and prevent injury. A platform the width of the cat walk is provided on the outside of the door at the same height as the cab floor which extends 3 feet beyond the doorway so that difficulty in reaching the handle from either side of the door will be avoided. Windows are included in the doors for rearward visibility for the crew. Conventional hinged doors were chosen over a more exotic design because they had numerous advantages in ease of operation and maintenance, low probability of jamming in the event of a collision and greater probability of retaining a good seal over the door opening over the life of the vehicle. Other design alternates considered were plug doors, sliding doors, servo-operated doors, and "air" doors that provide a moving curtain of air to seal out the external environment.

For emergency ingress-egress a number of options are available to the crew if for any reason they are unable to open either door. The roof has been fitted with an emergency escape hatch as shown in the top view of Figure 3-2, to be used in case of a roll over. This hatch has a minimum opening of 25 x 25 inches unrestricted emergency egress. Front windshields can be kicked out of their mountings in case of emergency with the use of "zip strips" and of course the side windows will be available as avenues of escape. In all, two rear doors, two side windows, two front windshields, and roof escape hatch are available in the cab for either escape or rescue.

3.6.2 Cab and Crewstation Lighting

It has been well established that proper lighting in a work environment is necessary to allow an individual to perform his duties in an efficient manner. All cab instruments with present design will be integrally lighted using a transillumination method. This method of lighting will offer the most uniform distribution of light across the face of the instrument panel and is easiest to balance so that all displays look equally bright. Transillumination also results in the least amount of stray light and gives better contrast between the instrument markings and background. If transillumination proves to be unfeasible upon further investigation, as may be the case with the large speedometer dial, other good lighting techniques, such as wedge lighting, should be used. It is acknowledged that trans-illumination is the most expensive way to light an instrument, but it is judged that the quality of the end product justifies any small increase in cost over present designs.

Control panels will have legends, controls and control position marks illuminated by using acrylic edge lighted plates. These light plates will offer a black opaque background with white lighted legends. All switches and switch positions will be identifiable during night operations using this technique. White lighting has been chosen for light plates, and instrument lighting, because colored range markings will be visible and a higher efficiency of light output is possible. It was determined that the color temperature of the white light would not be a significant issue in a locomotive application in that one color temperature would be "better" than another, but it is stressed that once a particular white is chosen it should remain a constant in the specification. This same statement also holds true for the surface brightness of illuminated indicia. As a starting point, it is suggested that a white light with coordinates of X= .446 and Y= .405 in accordance with MIL-L-27160C be used with a 2.0 foot lambert brightness. Since advanced lighting technology has not been routinely used in locomotive cabs, some testing will be required to determine optimum lighting qualities. All instrument and panel lights are controlled by dimming rheostats that give the engineer the capability to adjust the brightness level of his displays.

Cab dome lights are controlled by a switch adjacent to the exterior light controls. These lights are ceiling mounted to provide general illumination in the cab. Every effort should be made to evenly illuminate the cab from these sources at approximately 50 foot candles at 30 inches above the floor since their primary intended use is when the locomotive is stationary and crewmembers are moving about the cab, performing administrative duties or when maintenance personnel are aboard. auxiliary lighting is provided for each crewmember in the form of a light fixture attached to the writing surface provided. This fixture floodlights the writing surface at an intensity of 75 foot candles for making notations, reading train orders, and other short duration reading and writing tasks. Emergency lighting is provided by electroluminescent (EL) panels mounted in the cab ceiling and powered by a battery and inverter. Emergency light levels will be approximately 3 foot candles at 30 inches above the floor. These lights may be actuated by either an emergency brake application or an intense structural shock. EL panels were chosen because of their resistance to damage and low power consumption. Since conventional lighting methods involve fixtures, lamps and lenses they were rejected for emergency lighting because they could not be counted on to remain intact in the event of a collision, derailment, roll-over, or other accident where structural deformation may take place. EL panels can be bent, twisted and punctured and still operate for a short time. No fixtures are needed, and no glass is used in their manufacture, making the panels almost "accident proof".

3.6.3 Environmental Control

The environmental control of the locomotive cab encompasses a number of areas. The subjects discussed here are acoustic environment, heating, ventilation and air conditioning. In view of the fact as has been stated that locomotive crews may spend a twleve-hour day in the cab, it is recommended that the acoustic environment of the cab should not exceed 70dBA. Although OSHA allows a maximum of 90dBA in a work environment for an 8 hoyr day, 65dBA is desirable. The 50 percent greater exposure time, human data on the effect of an excessively loud environment on hearing impairments, and the fact that crewmembers must communicate suggests that a lower level for the ambient acoustic environment is desirable. Short time (15 seconds) sound levels should not exceed 90dBA.

Control of undesirable noise in the cab may be accomplished by any number of methods such as (1) controlling noise at its source, (2) controlling noise and vibration transmitted through locomotive structure by the use of cab isolation mounts (3) use of insulation materials inside the cab for noise absorption (4) use of materials and construction methods that prevent the cab from resonating in response to noise sources. Care must be taken, however, to insulate the cab in such a way that necessary acoustic stimuli from the external environment such as other train whistles or torpedoes can be heard.

Suitable control of the atmospheric environment can be achieved by the proper allocation and utilization of heating, cooling, and ventilating equipment. For maximum physical comfort while noramlly dressed appropriate to the season or climate, the optimum range of effective temperature for accomplishing locomotive cab work is: (a) 70-80° F in a warm climate or during summer, (b) 65-75° F in a colder climate or during winter. Humidity values should approximate 45 percent relative humidity at 70°F.

Heating and air conditioning of the cab is controlled by a slide type thermostat and two selectors for either heat or air conditioning, as previously noted. Ventilation will introduce a minimum of sixty cubic feet per minute into the cab with two thirds being outside air, and air flow will be at least 65 cubic feet per minute. Intakes for fresh air will be mounted behind the cab to preclude the introduction of flaming liquids in case of a collision; and toxic gases, vapors, dust and fumes during normal running. Temperature in the cab will be held relatively uniform with a maximum 10° F differential between air at floor and head level.

3.6.4 Crew Accommodations and Interior Finish

Considering the length of the tour of duty on a locomotive, it was considered essential that the engine crew have the proper facilities available to sustain them during the period they are on the locomotive. A lavatory is located at the rear of the cab containing a toilet bowl, sink, hot and cold water, light fixture and shatterproof mirror. A drain is provided in the floor so that the entire compartment can be hosed down if necessary. Walls, floors and fixtures will be of molded construction and all corners will be rounded to prevent injuries, dirt accumulation and facilitate cleaning. The toilet may be of several types but holding or treatment tanks must be outside the cab compartment. Hoses and connecting lines must be located behind easily removable panels to preclude dirt accumulation and facilitate maintenance. The lavatory enclosure must be ventilated by use of an exhaust fan and fresh air intake. Air flow should be at least 30 cubic feet per minute.

The water supply for the sink and water cooler and the chemical supply for the toilet have been identified as potential problems due to freezing weather. The chemicals used in the toilet should have a low freezing point to prevent damage to holding tanks and a drain valve for the water supply should be located near the engine cooling water drain cock. An alternative is to supply water to the crew in plastic bags contained in cardboard boxes that would fit in an adjacent storage compartment.

A small refrigerator, which doubles as a water cooler, for storage of lunches and cold beverages is located next to the lavatory. A storage locker is located directly underneath for personal gear.

Cab floors are of a grooved non-skid type rubber base linoleum that is easy to clean and durable. Walls and ceilings should be easy to clean, resistant to being scratched or marred, and sound attenuating. One possibility is a paint known as "Silent Paint". This is a constrained layer, broad temperature damping latex paint that is applied in the same manner as ordinary paint but damps thin panel vibration and reduces its response to resonance. In addition to painting cab walls with this material, it may be advantageous to coat the engine compartment with this material to cut down on some of the noise in the immediate proximity of the cab.

3.6.5 Seats and Restraint System

The functional requirements and physical environment of the locomotive has resulted in a seat that also functions as part of a passive restraint system. The seat mount has the capability of being adjusted in all three planes so that the engineman can comfortably operate all the controls and observe the displays provided for him. The seat pan is slightly contoured to give good support to the thighs and buttocks.

Padding should be of a firm foam material at least three inches in thickness. The back rest provides good lumbar support by providing extra padding in this area. Head restraints are provided as part of a restraint system for the purpose of providing whiplash protection in case of a run-in and are not intended as head rests. The seat back rake is adjustable to a small degree, and its nominal angle is 5 degrees. A maximum of 20° from the vertical can be set into the seat back.

Occupant protection criteria were established via inputs from EMD and DOT/TSC-821, Rail Safety/Equipment Crashworthiness Study. Passive restraints have been chosen over active restraints, such as seat belts and shoulder harnesses, because the length of time that the engineer is in the locomotive, and his need to frequently shift position and look out the window, make the active restraints an unreasonable method of protection. A restraint system that is not used, has been proven by highway accident statistics to be a useless piece of equipment. Some people do not wear seatbelts and harnesses in their automobiles for even short periods and it is not reasonable to believe that engine crews will wear a restraint system for twelve-hour stretches. The passive measures are to properly pad the edge of the consoles and glare shield to prevent injury in case of a rapid deceleration, and to make all protruding controls a frangible type. However, a problem is incurred here in that a control that will break away to prevent serious injury in the event it is struck by a body member may also break under heavy use. Selection of materials and structural design of controls must be weighed carefully and appropriate engineering tests must accompany the design.

Additional occupant protection criteria are shown in Figures 3-15, 3-16, and 3-17. The left column contains criteria that are important from an occupant protection standpoint. The right column is requirements from the human factors engineering standpoint. During the cab design every effort was made to incorporate the occupant protection criteria set forth in these figures. The conceptual seat discussed earlier was designed for occupant protection, particularly since the cab seat is responsible for the majority of all noncollision/derailment cab injuries. Equipment in the cab has all corners rounded, edges padded, and flush mounted auxiliary equipment such as fire extinguishers and fuse racks. Cab structure was designed - in a conceptual manner - for maximum crashworthiness while not sacrificing vision or ingress-egress requirements and is discussed below.

3.6.6 Cab Structure

Inputs from Contract DOT/TSC-856 and EMD have assisted the design team in defining the locomotive crash environment and a general set of criteria to survive in crash environment. Deflection/collision posts have been provided in the full height of the cab on each forward corner as well as in the center at a 30° angle and anticlimbers provided for

OCCUPANT PROTECTION CONSIDERATIONS

STRUCTURAL

- LONGITUDINAL IMPACT
- SIDE IMPACT
- ROLLOVER

OCCUPANT RESTRAINT

- RESTRAIN OCCUPANT
- DISCOURAGE WANDERING

HUMAN FACTORS ENGINEERING

- EXTERNAL VISION REQUIREMENTS
- INGRESS - EGRESS REQUIREMENTS

HUMAN FACTORS ENGINEERING

- RESTRAINT SYSTEM AVAILABLE
- ALLOW "LEG STRETCHING"
- ALLOW MOVEMENT TO CHECK TRAIN
- ALLOW BODY MOVEMENT TO DAMPEN ROLL AND SHOCK
- ALLOW FREQUENT SHIFTS IN POSITION

Figure 3-16. Occupant protection Criteria (continued)

OCCUPANT PROTECTION CONSIDERATIONS

WINDOW DESIGN

- SHATTERPROOF
- KEEP OCCUPANT IN
- KEEP FOREIGN OBJECTS OUT
- PLACED BEYOND "FLAIL ZONE"

HUMAN FACTORS ENGINEERING

- VISIBILITY REQUIREMENT

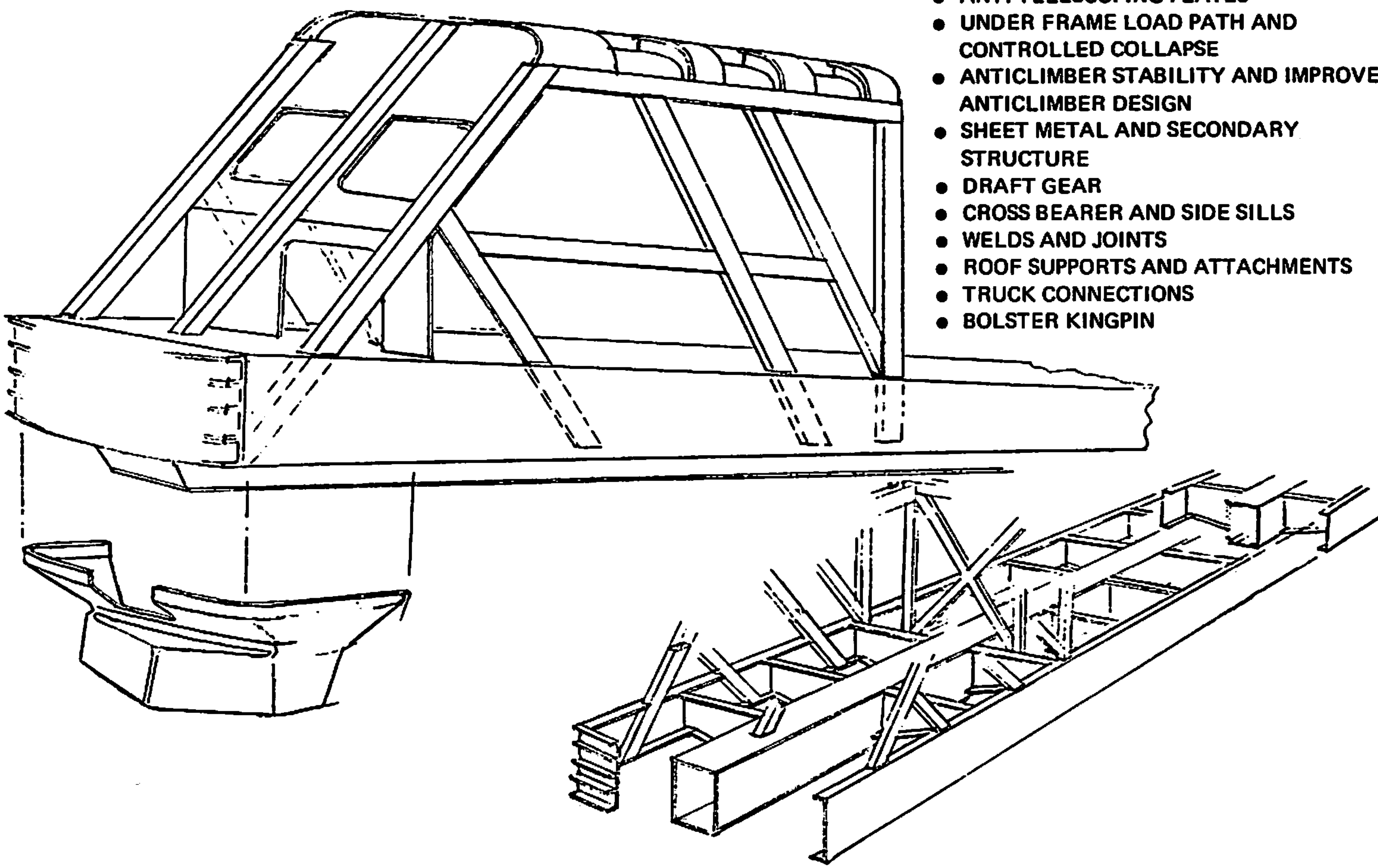
DOOR DESIGN

- NOT DEFORM ON IMPACT
- KEEP OCCUPANTS IN
- KEEP FOREIGN OBJECTS OUT
- EMERGENCY EGRESS
- FACILITATE RESCUE

HUMAN FACTORS ENGINEERING

- EASE OF ENTRY/EXIT
- CONVENIENT LOCATION
- EASY/SAFE OPERATION

Figure 3-17. Occupant Criteria (continued) protection in collisions. Roof and side structural members have been located to provide a load path to the underframe and afford protection in the event of a side impact or rollover. Cutaway views of the structural members can be seen in Figures 3-18 and 3-19. It is emphasized that the sizes, dimensions, or placement of these structural members are not meant to be definitive or exact in engineering sense, but rather represent an approach to the problem of crashworthiness allowing the use of good human factors engineering in the cab design.



REQUIREMENTS

- COLLISION END POSTS
- ANTI TELESCOPING PLATES
- UNDER FRAME LOAD PATH AND CONTROLLED COLLAPSE
- ANTICLIMBER STABILITY AND IMPROVED ANTICLIMBER DESIGN
- SHEET METAL AND SECONDARY STRUCTURE
- DRAFT GEAR
- CROSS BEARER AND SIDE SILLS
- WELDS AND JOINTS
- ROOF SUPPORTS AND ATTACHMENTS
- TRUCK CONNECTIONS
- BOLSTER KINGPIN

Figure 3–18. Possible Structural Layout for Baseline Crashworthy Cab

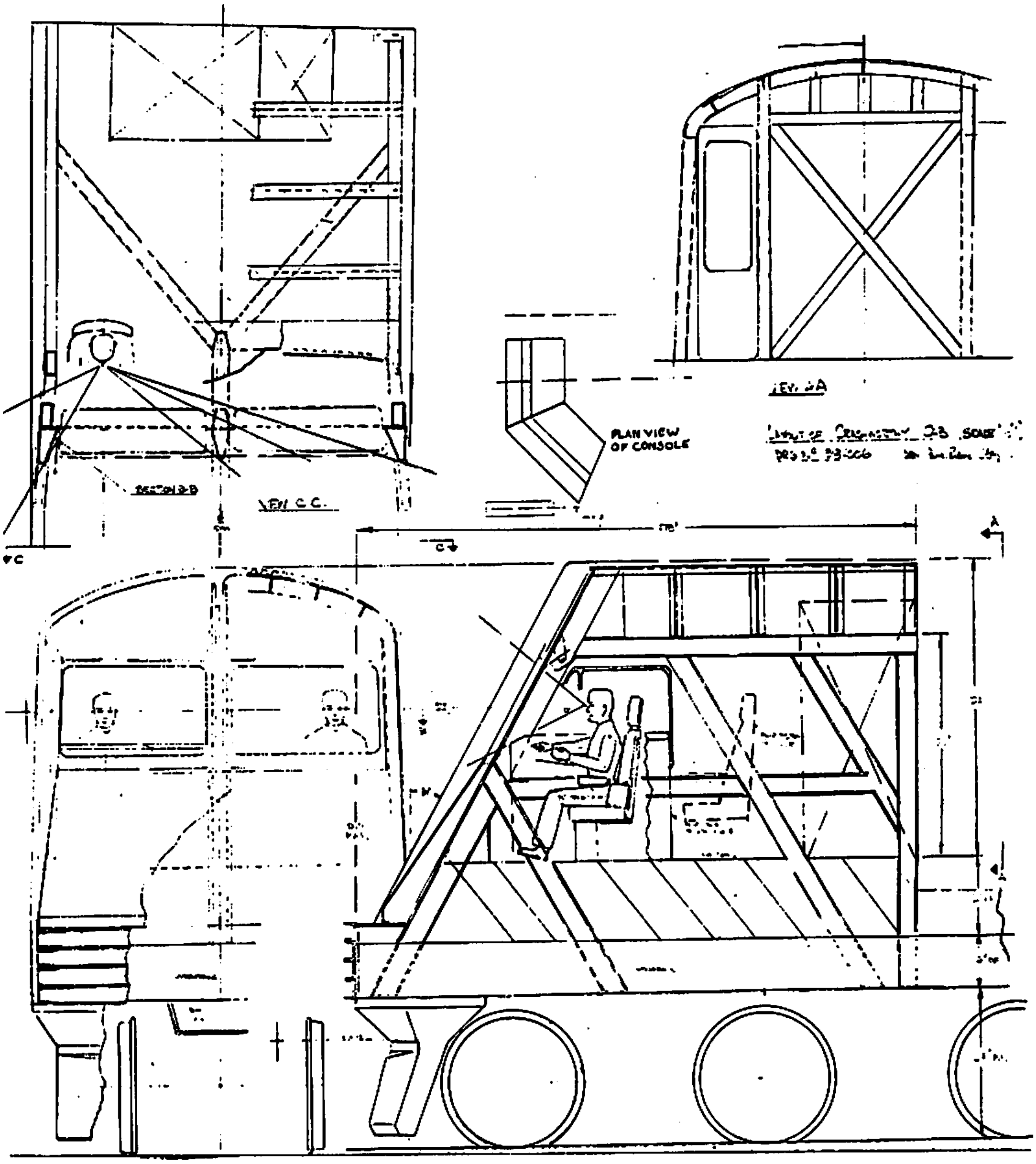
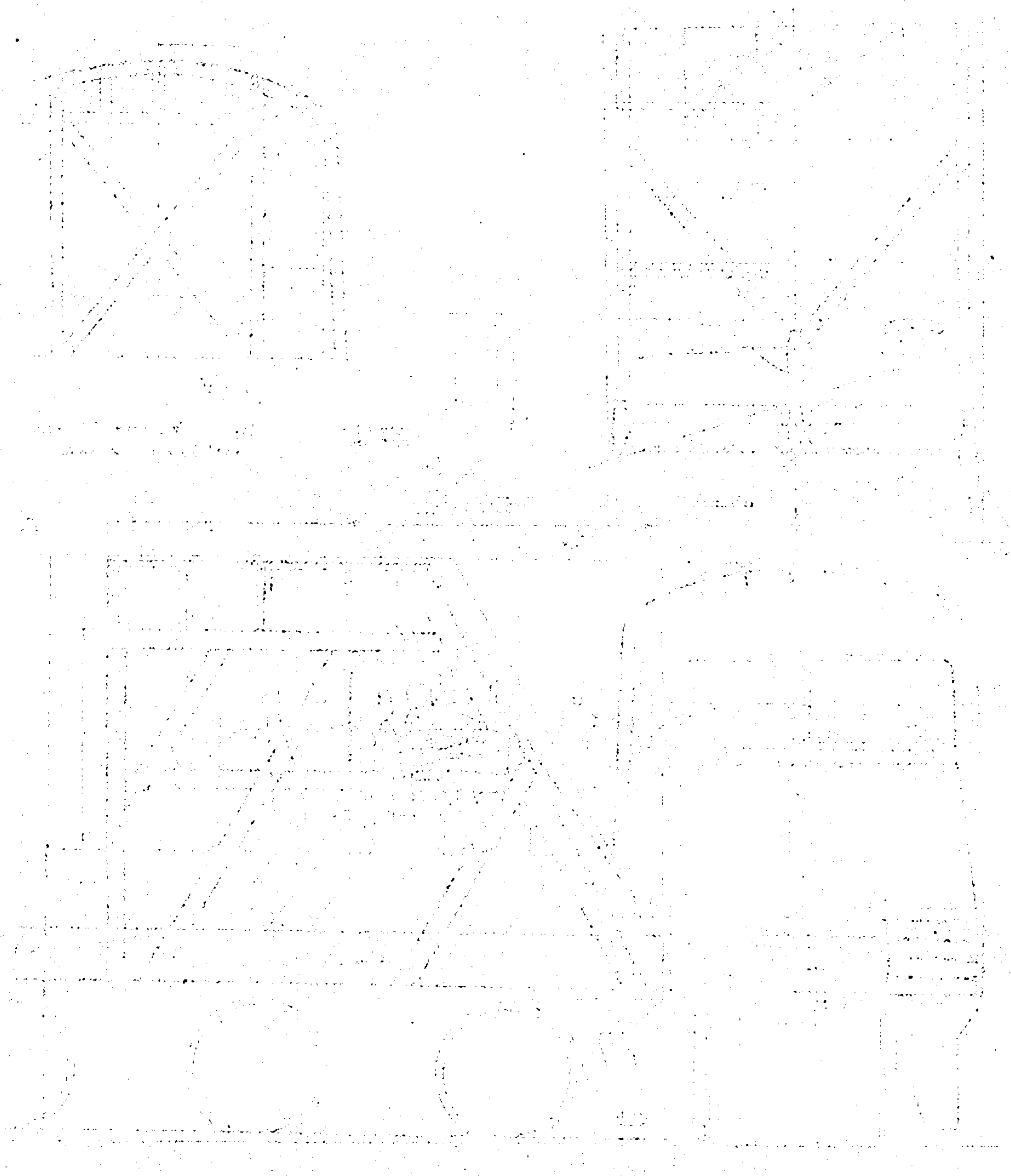


Figure 3-19. Possible Structural Layout for Baseline Crashworthy Cab (continued)



4. ALTERNATE CONCEPTS

This section presents some alternate concepts that were developed during the course of the study. The recommended design presented in Section 3.0 is a mix of selected features from each of the alternates considered and are discussed below.

4.1 IDLER CAR

As stated the object of this study is to design a locomotive cab that was optimum from the cab crew's standpoint. However, early in the design stage it was recognized that building a cab on the front end of an existing locomotive carried with it the recognition of a wide variety of existing constraints in the interfaces between the cab and locomotive subsystems. These interfaces were structural, mechanical, electrical, pneumatic, and included significant crew interfaces. For example, noise and vibration would still be transmitted through the locomotive structure and space for crewstation equipment installation may conflict with existing locomotive hardware. To circumvent some of these engineering problems, it was postulated that the study team might gain more freedom and place many of the problems in better perspective if the cab was designed as a distinct vehicle, trainlined to and pushed via the motive power of the locomotive. The idler car is shown in Figure 4-1. Essentially, the crew work station is the same as that shown for the recommended design, as is the general cab envelope and crashworthy structure.

Some differences may be noted in the general layout however. First, the idler is double ended. That is, a complete crew station is located at each end of the car for convenience in moving in either direction. A second consideration is the additional weight imposed on the trucks by the structural additions provided for crashworthiness. Rather than ballasting the car, a second crew compartment was located on it to implement the operational utility that accrues with use of a dual control locomotive. Ingress and egress are unchanged and the convenient hand rails and stairs retained. In the case of a multi-locomotive consist, some savings in cost might be realized if the idler were propelled by less expensive "B" units where only one cab would be used instead of a string of "A" units with an inactive cab in each one. Some disadvantages are present in the idler car concept. It is recognized that "B" units are not as flexible in service for road switching, for example, as the traditional "A" units. However, it should be noted that the idler car's principle use is as a conceptual tool during the design. The idler itself may require switching if an auxiliary power unit was not incorporated; and structurally it would have to withstand high loads if it were placed in the middle of a consist. It is suggested that this alternate would be a viable candidate for further engineering evaluation.

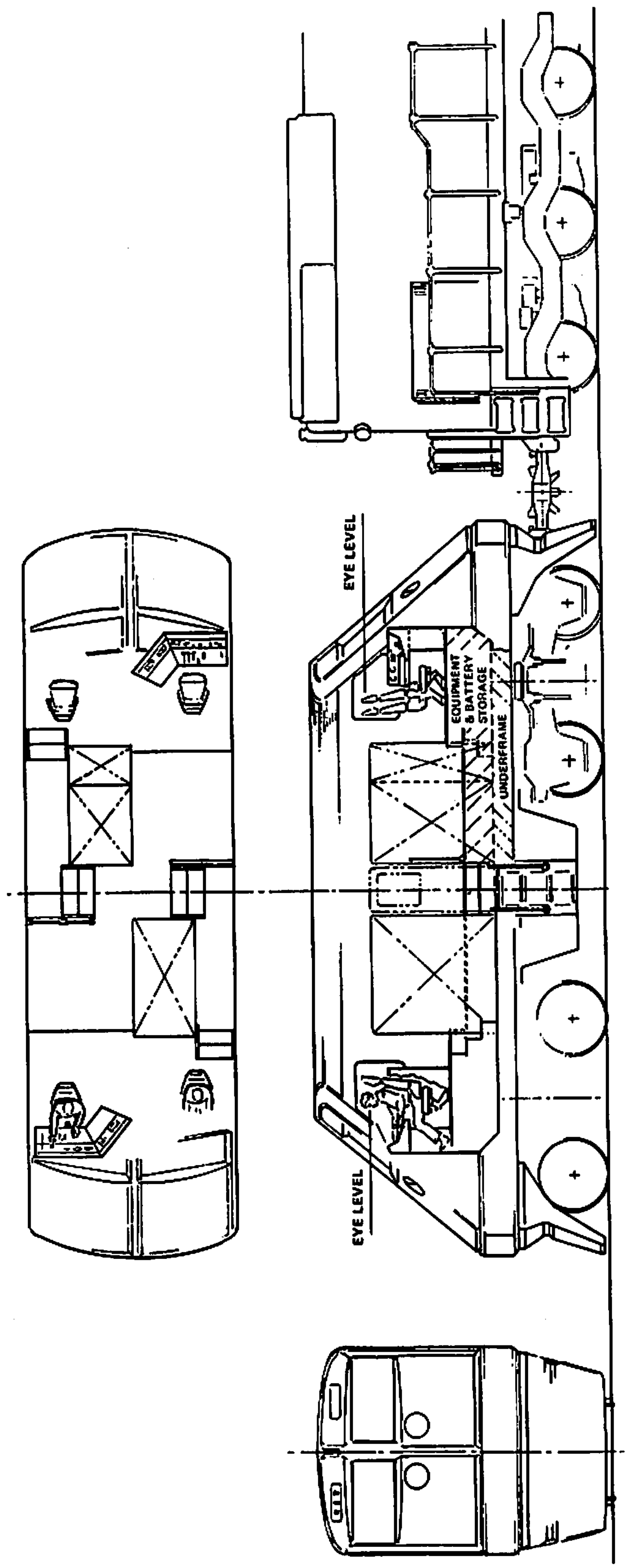


Figure 4–1. Idler Car Concept

4.2 MOVING PLATFORM

The alternatives are shown in Figure 4-2 to 4-2C. The engineer (55th percentile) is shown seated on a moving platform in Figure 4-2. A display console and chair are mounted on the platform. It can be rotated left and locked in either the 90° or 180° positions. The locomotive can be operated with equal facility from each of these positions.

The display console contains two video displays and an annunciator panel identical to the one in the recommended design.

Two control panels are located forward of the chair armrests. The armrests swing away easily, as shown in View A ., to permit rapid egress in the event of an emergency.

4.2.1 Displays

The displays shown are not firm designs, but rather concepts that evolved during examination of possible state-of-the-art techniques that appeared feasible by 1990. The first concept, designated Video 1 is shown at the left of the display panel. The conventional arrangement of dials and gauges was discarded. Instead the parameters (speed, power, drawbar force, brake cylinder pressure, brake pipe and equalizer reservoir pressure) usually displayed with conventional instrumentation are selectable as one of several display options. Traction motor loads and draw bar forces for all locomotives in a consist can be selected. Locomotive brake cylinder pressure is yet another option to inform the engineer that no residual air pressure is causing brakes to drag.

A wider variety of information is desirable and could certainly be developed. For example, sensors could be placed along a train to detect hot boxes, dragging wheels, sticking brakes or, in fact, any malfunction that generates excessive heat. It should be noted that the information when displayed to the engineer could come either directly via trainline or be relayed from the wayside. A printed message from the dispatcher is another example of how the concept might be developed. The message could be displayed directly and replace written train orders which are often passed to the crew on the fly. The message would remain "on" until acknowledged by the engineer. Finally, closed circuit video monitors could be mounted on the locomotive to monitor malfunctions such as shifted loads or dragging equipment.

These concepts appear worthy of further study because of the range and flexibility of information that could be made available to the engineer.

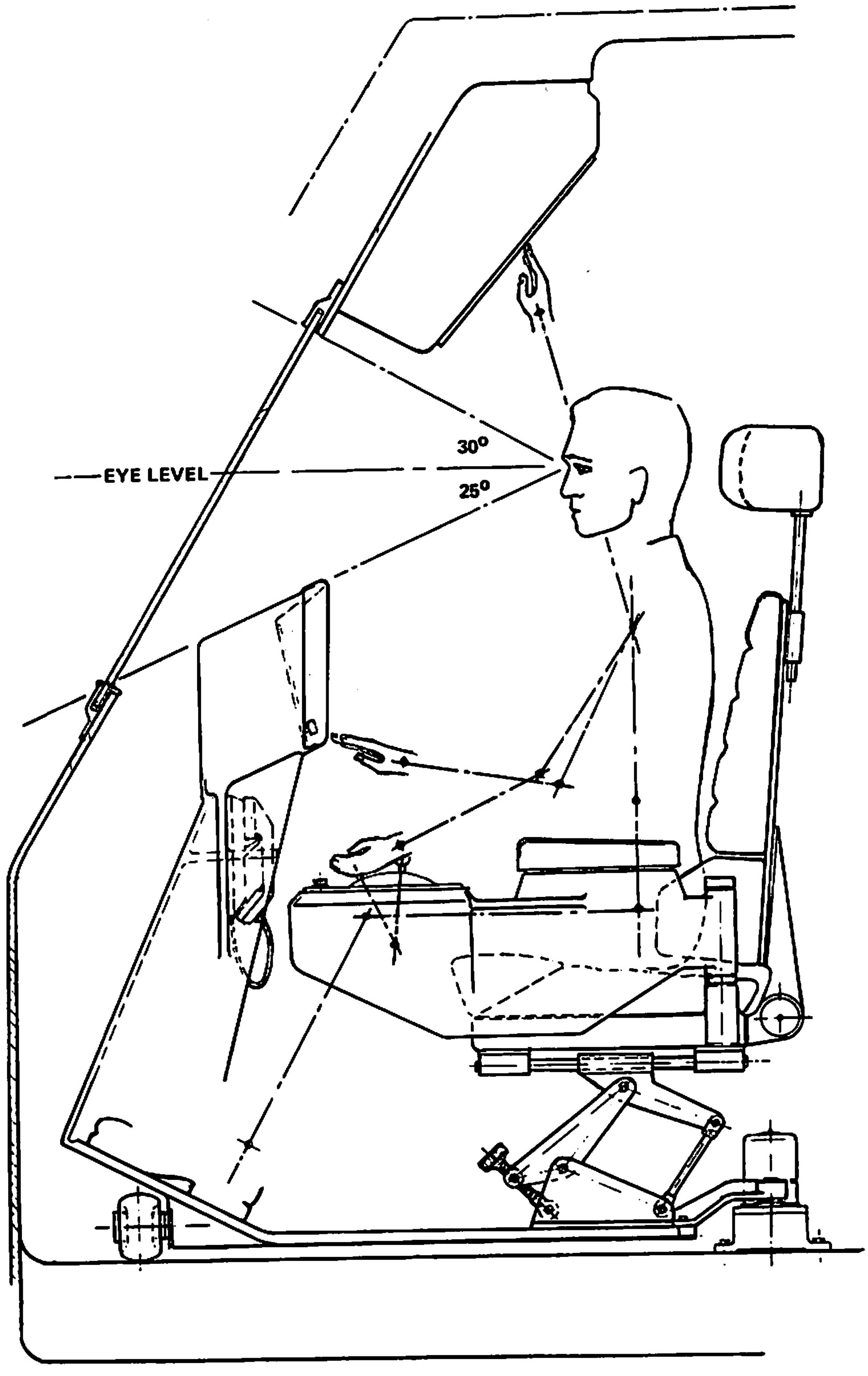


Figure 4–2a. Rotating Crew Station

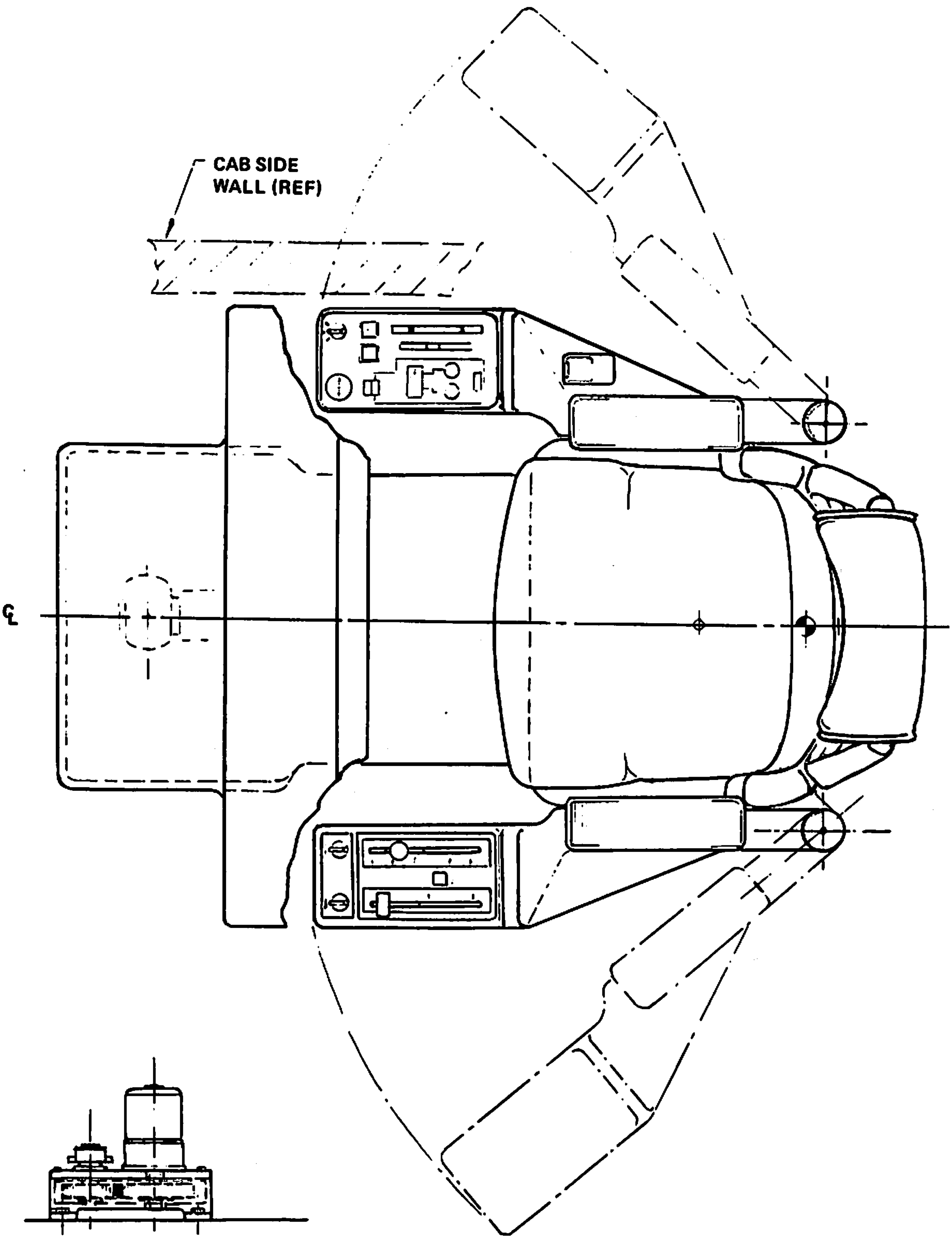


Figure 4–2b. Revolving Platform

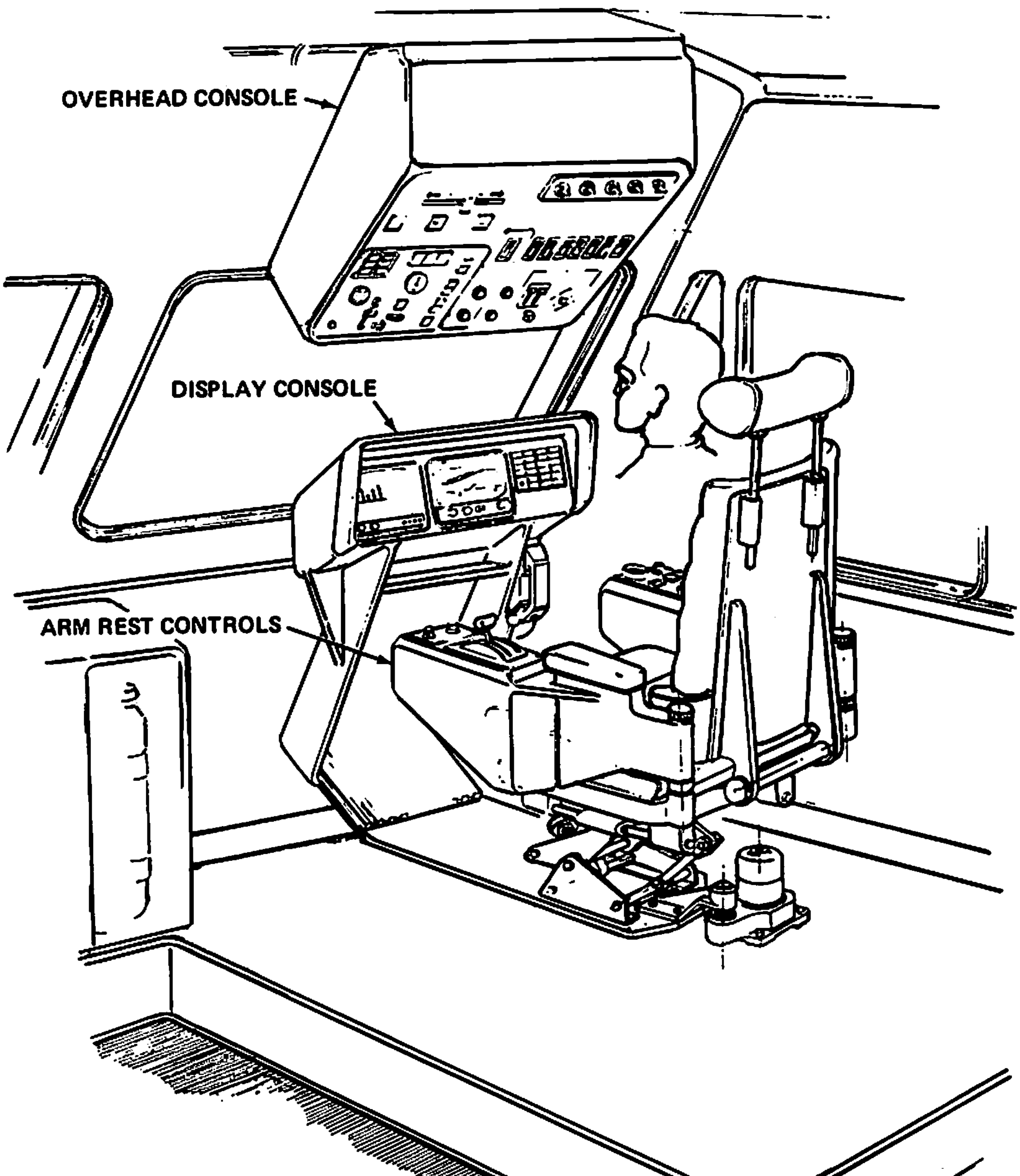


Figure 4—2c. Three-Quarter View Revolving Platform

4.2.2 Chair Controls

The following control functions are located on the right hand side of the chair as shown in Figure 4-3. (1) The EMERGENCY STOP button with a guard to prevent accidental activation. This control was located in the upper left corner and requires a deliberate motion for activation. (2) The next control is the DIRECTION SELECTOR. Originally this was a lever-locked toggle switch oriented so that FORWARD was toward the front (short hood) of the train and REVERSE was toward the long hood with NEUT in the center. This orientation was acceptable as long as the chair was locked forward. If the chair was turned to face the rear (long hood), the orientation was backwards. One solution considered was to remove the REVERSE position and interlock the FORWARD input so that when the chair was rotated 180°, the FORWARD position would still point in the direction that the locomotive moved. This would require a software lock-up that would increase costs and even this solution did not cover the occasion when the chair may be rotated only 90°. To avoid this, an alternative was necessary and the rotary selector was adopted. With this control direction orientation is not possible, but reverse will always be long hood no matter which direction the chair is facing. (3) A MANUAL/AUTO select pushbutton switch was added to enable the engineer to choose his method of speed control. If placed in the AUTO position, the engineer dials the selected speed. After setting in command speed, he presses the ENTER button and the software speed control system takes over to maintain the speed. The software system would apply throttle when needed and dynamic brake to maintain speed at the selected value. The engineer can manually override the system and use the handwheel to control the speed or dynamic braking as desired. Incorporation of both functions on the handwheel precludes the possibility of using dynamic brakes when the throttle is applied or vice versa. When decelerating the train using either the full automatic speed control or the dynamic brake portion of the handwheel, blending of the dynamic and independent brakes will take place. That is, at low speeds when dynamic braking fades out, the independent brakes will gradually and automatically apply to sustain the same rate of deceleration, without sliding the wheels, until the train comes to a halt or the controls are placed in idle. (4) The engine pushbutton switch is used any time the engine needs to be shut down including emergencies. It is protected by a plastic guard so that it will not be inadvertently applied. (5) The locomotive bell is a pushbutton switch. Activation of this switch will ring the bell and it will ring until the switch is pushed a second time. When the bell rings, either automatically or manually, the switch lights up.

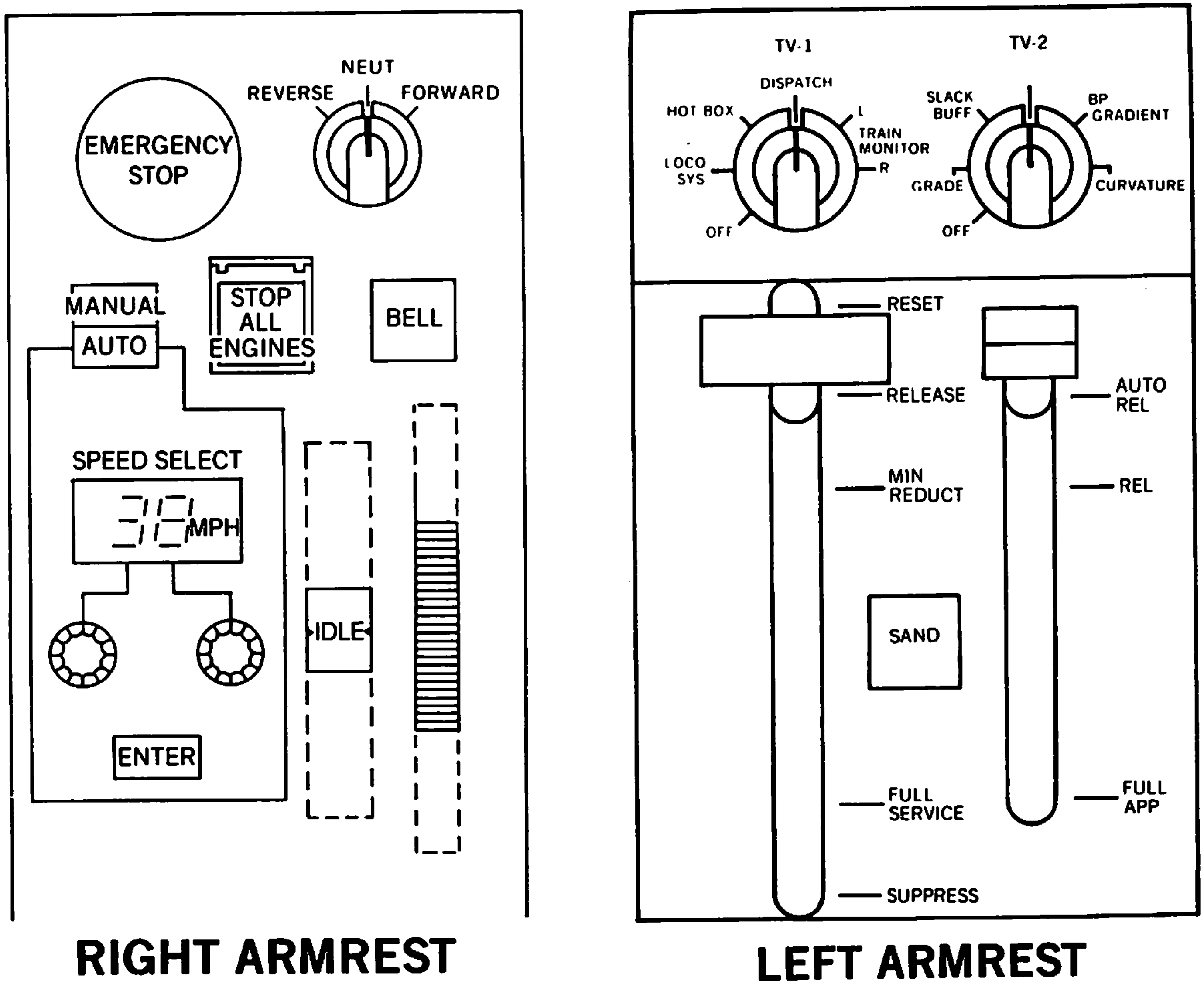


Figure 4-3. Armrest Controls, Chair Controller

The left hand arm rest extension contains CRT controls and the normal train braking functions. A description of the controls is as follows: (1) The TV-1 selector switch and (2) The TV selector switch enables the engineer to select different parameters to display on the CRT's located in the instrument panel in front of him. Located on the instrument panel is a switch which will enable the engineer to transfer parameters between TV-1 and TV-2. The capability will be used when one of the TV's is inoperative. The parameter selector of the live TV must be turned to the OFF position for the transfer to take place. Selector type switches have been chosen as control devices for several reasons:

a. They are made so that each discrete position has a detent which allows for accurate setting.
b. Indication of position setting is built into the switch.
c. Only one setting at a time is possible.

(3) The train brake is a lever that swings through an arc. As it swings through the arc there are detents at the points marked on the surface. To get from RELEASE to RESET requires the positive action of lifting up the control and moving it forward. To go from FULL SERVICE to SUPPRESSION requires the same action with the exception of moving the control to the rear. Braking betweent the settings of MIN REDUCT and FULL SERVICE is a continuous application. (4) The independent brake is similar in concept. To go from RELEASE to AUTO REL requires lifting up the control and moving it forward. In the AUTO REL position a software device will prevent brake pipe pressure build-up to the independent brakes when the train brakes are applied.

The selection of levers for brake functions is based on the following rationale. Push button switches were used because they are relatively simple and easy to operate. However, if the train brake release push button were inadvertently hit when one was trying to apply the brake, it would dump brake pipe pressure and render the train brakes useless temporarily which could result in a dangerous situation. This possibility makes selection of pushbuttons impractical and so slide switches were considered. The advantages of the slides are that (1) a panel depth of 3" could contain this type switch. (2) The slides could be kept close to the panel surface because it is not necessary for the operator to get his fingers underneath it. One disadvantage in the use of slide switches is that the operator cannot tell their position by feel alone, unless this feel is artificially designed into the control. The final selection was the lever control on which positioning can be sensed by determing where one the arc the hand is at a given time. (5) The sanding control, although frequently used during acceleration, was placed close to the independent brake for use in conjunction with it when required, to free the right hand for throttle control.

In front of the chair, is the front instrument panel. This panel is affixed to the chair and rotates with it so that it is always opposite the engineer. It contains the following indications: (1) On the right hand side is the advisory panel containing lights which indicate to the engineer that some corrective action is required. (2) TV-2 on which are shown the parameters selected by the control on the left arm rest. (3) TV-1 on which are shown the parameters selected by the other control on the left arm rest. Underneath the panel, below the CRT's is the control which will enable the engineer to transfer TV-2's parameters to TV-1 and vice versa. This control is hidden under a cover that can only be opened for testing or for the actual transfer operation. This latter feature is to preclude accidental erasure of the display. On the right side of the platform just below the instrument panel, is the communication handset.

5. PRIMARY CONTROL DISPLAY DEVELOPMENT

To indicate the relative development effort for the cab, an analysis was performed and is shown below. The first column lists those primary functions identified during the analysis of the conceptual baseline requirements. The second column lists the functions currently implemented in present cabs. The third column lists the requirements for the recommended cab design. The fourth column presents the degree of effort required. The "None" Category A indicates that hardware items exist, off the shelf, to do the job or at the very least, some modifications would be required (i.e., pushbuttons). "Moderate" was defined as indicating that the technology for producing the hardware item exists, but engineering effort would be required for this particular application (i.e., instruments). "Extensive" was defined as indicating that in depth engineering analysis, development, test and research would be required in the areas of sensing, transmitting, integration and display techniques and hardware for displaying train information.

6. SUMMARY

This report has present the work accomplished under items 1 and 2 of the contract statement of work. Current locomotive cab technical data and designs were reviewed along with their associated operational requirements. Based on an analysis of this data, a set of functional requirements were developed using a system engineering approach. This demonstrated analytic tool provided a means to systematically define the equipment, personnel, facilities and procedural data required to implement identified functions. An information and action requirements analysis was accomplished to define: (a) stimulus inputs to the engineer, (b) responses, (c) information feedback requirements, and (d) planning aids for improved train handling. Safety aspects were given a high priority in terms of potential for design induced increments in crew performance, lack of psychological and physiological stresses, crashworthiness, occupant protection, and upgraded train handling.

Human factors criteria were developed and problem areas identified. Having defined a baseline, a detailed engineering analysis was performed. To supplement this analysis, projections were made of train handling requirements which are likely to evolve by the year 1990, and were incorporated into the functional requirements. Locomotive and right of way constraints were determined and alternate locomotive cab designs developed. A detailed analysis of the alternates was done to optimize the cab work and living space, control console, train diagnostics, life support, occupant protection, safety, reliability and cost.

One cab design was selected and a recommendation made to the technical monitor that the concept be developed further. Upon approval, work has started on the fabrication of a one-tenth scale model of the recommended design.

TABLE 5-1. PRIMARY CONTROL/DISPLAY COMPARISON

FUNCTION	PRESENT	RECOMMENDED	DEVELOPMENT REQ
Direction	Lever	Toggle	None
Throttle	Lever	Thumb Wheel	Moderate
Dyn Brake	Lever	Thumb Wheel	Moderate
Train Brake	Lever	Lever	Moderate
Ind Brake	Lever	Lever	Moderate
Horn	Lever	Foot Pedal	Moderate
Bell	Push-Pull Knob	Push-Pull Knob	None
Sand	Toggle	Push Button	None
Brake Pipe Pressure	Round Dial	Verticle Tape	Moderate
Equal Res Pressure	Round Dial	Verticle Tape	Moderate
Main Res Pressure	Round Dial	Round Dial	Moderate
Brk Cyl Pressure	Round Dial	Round Dial	Moderate
Traction Mtr Load	Round Dial	Round Dial	Moderate
Locomotive Draw Bar Force	None	Round Dial	Moderate
Speed	Round Dial	Round Dial	Moderate
Brake Pipe Venting	Audible Signal	Annunciator	Moderate
Air Flow	Round Dial	Round Dial	Moderate
Instrument Lighting	Indirect	Trans-illuminated or Wedge	None
Grade	None	CRT	Extensive
Curvature	None	CRT	Extensive

TABLE 5-1. (CONTINUED)

FUNCTION	PRESENT	RECOMMENDED	DEVELOPMENT REQ
Train Draw Bar Force	None	CRT	Extensive
Brake Pipe Gradient	None	CRT	Extensive
Emergency Brake	Lever	Push Button	Moderate
Engine Stop	Lever	Push Button	None
Control Deactivation	Control Removed	Key	None

7. RECOMMENDATIONS

In the course of this contract certain items have come to be regarded as being important issues in the area of locomotive cab design that are outside the scope of the contract, yet deserving serious study and analysis. Insofar as practical, the design team has used their best judgment to fill in gaps in data and projecting the state-of-the-art in the realm of railroading as discussed in the initial portions of this report.

The specific items identified that need further research and development are listed below. It should be stressed that this is a partial list in that other items falling into this category may appear as the contract runs its course.

7.1 PHYSICAL ANTHROPOMETRY OF LOCOMOTIVE ENGINEERS AND BRAKEMEN

In this design effort, the anthropometric dimensions of the U. S. adult male population have been used. No data on the anthropometrics of the railroad population was found by the design team, yet it is a crucial element of any crewstation design. It is suggested that useful anthropometric measurements be taken of a representative sample of engineman and locomotive brakemen, so that future crewstation designs and design modifications can be based on established population dimensions.

7.2 VANDALISM

It came to the attention of the design team in the very early stages of design that vandalism of the workplace is a chronic problem on locomotives. It is suggested that this problem be analyzed and dealt with in two parts. First, incidents of vandalism should be analyzed to determine whether they are malicious or functional. For example, are the colored jeweled lenses on annunciator lights stolen or do they fail in service? If stolen, is it because of simple malice or due to the annunciator bulb not shining brightly enough through the lens? Secondly, fixes should be designed for the targets of functional vandalism. The sociological or psychological course of malicious vandalism must be detected and dealth with where possible in a positive manner.

7.3 TRAIN HANDLING DISPLAY

The train handling display in the recommended design will require a great deal of research and hardware development to become an integrated display. TSC has under development a DRAFT-BUFF indicator that is already a step in this direction, but the parameters of drawbar forces, brake pipe pressure gradient, grade and curvature are critical parameters in train handling that must be sensed, transmitted and integrated for this display to be a reality. Therefore, it is recommended that future research continue on these problems to achieve this.

7.4 BRAKING

In the area of train braking, it is suggested that the feasibility and utility of a blended dynamic and independent brake be investigated. The concept here is to blend in the independent brakes as the dynamic brakes fade out at low speeds. This concept does not affect crew station design as such, but allocates the blending function that now is performed by the engineman, with the attendant potential risks of excessive buff forces and flat wheels, to an automatic blending system.

7.5 IDLER CAR

The idler car concept should be investigated from the economic, train/ handling, crashworthy, and crew comfort standpoint.

7.6 CAB SIGNALS

The main display panel in the recommended design has a cab signal indicator. Since the subject of cab signals is closely linked to railroad operating procedure and the present ground signal design, the format for cab signals is as varied as the railroads on which they are used. An area for human engineering research is to find an optimum display format for cab signals.

7.7 THROTTLE/DYNAMIC BRAKE

The combination throttle and dynamic brake handwheel in the recommended design has raised some questions as to whether or not it is appropriate as a control. While this contract will involve some limited performance testing in a mock-up, it will not result in a conclusive statement on the "effectiveness" of this control. To properly test the performance of enginemen using this control, it should be tested in a real world situation either in service or in a simulator or demonstrator, to compare it to more traditional controls found on extant locomotives

7.8 WORK STATION

The adequacy of the entire cab as a cohesive and functional workstation should be tested in an operational setting. Mock-up evaluations by the user population is a valuable tool, but only when the design is tested in the atmosphere it was intended for can its worth truly be measured. It is suggested that a fully functional cab be developed and operationally tested or to evaluate its utility and refine its weak points.

7.9 LIGHTING

As pointed out in the section on cab habitability, lighting techniques used in the current generation of locomotives is not optimum. It is suggested that research be conducted to determine the crewstation lighting needs of the locomotive engineer on both a qualitative and quantitative level. The results of this study should then be applied to the crewstation hardware design and tested in both a lighting mockup and on in-service vehicle. The results of this analysis testing and evaluation should then be compiled and formed into an engineering specification for locomotive cab design.

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APPENDIX A

LEVEL THREE FUNCTIONS

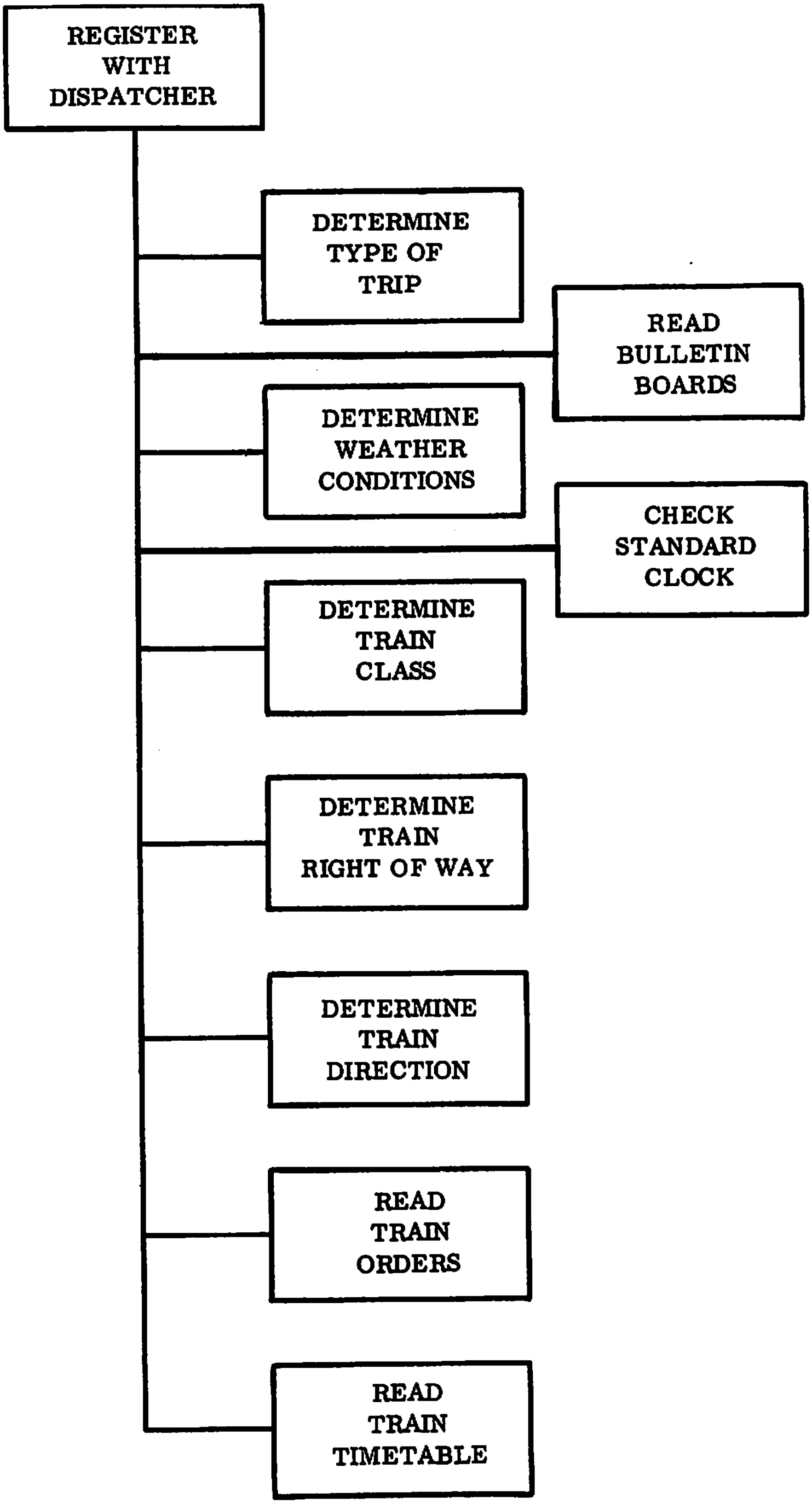
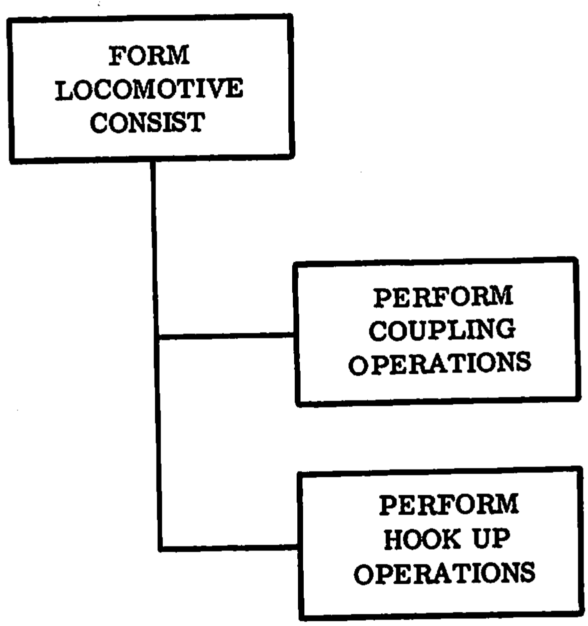


Figure A–1. Level 3 Crew Functions



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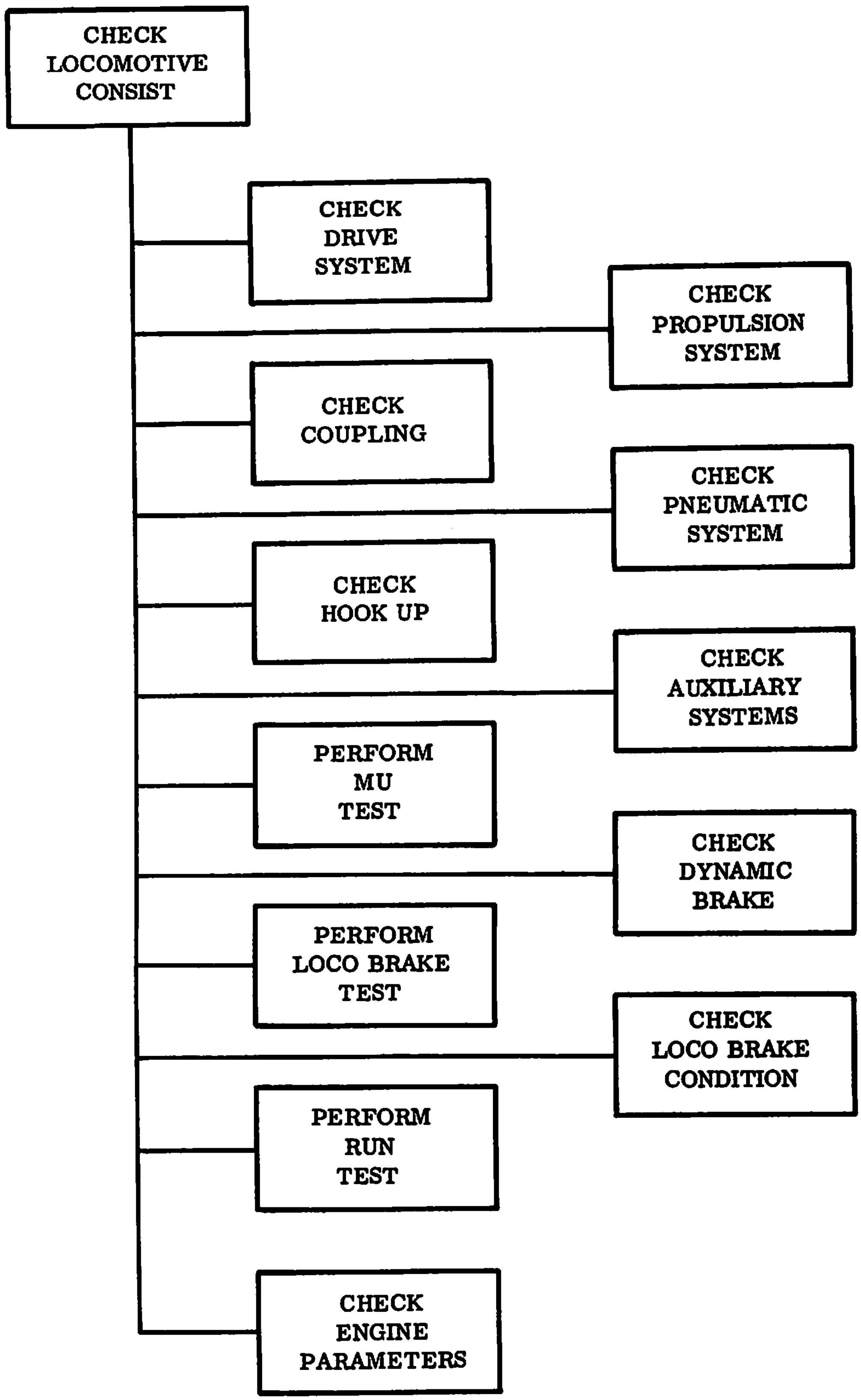

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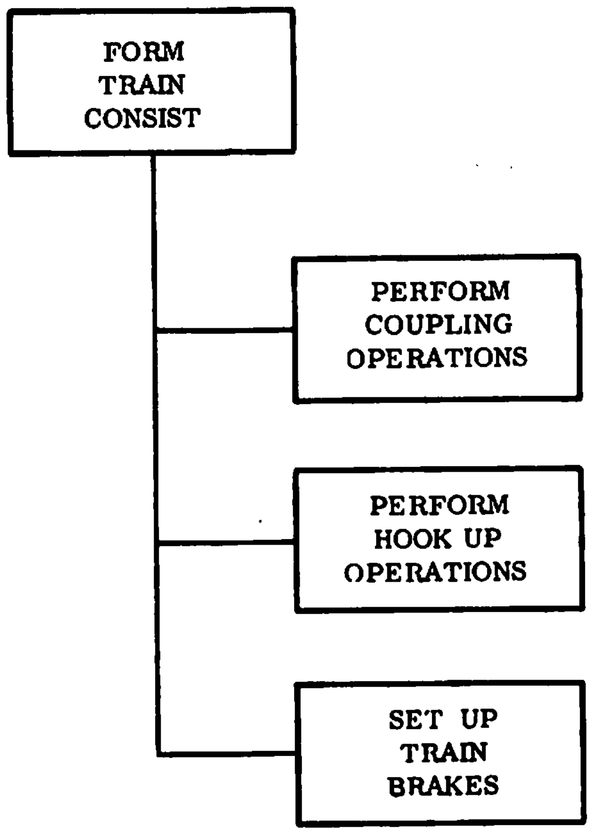

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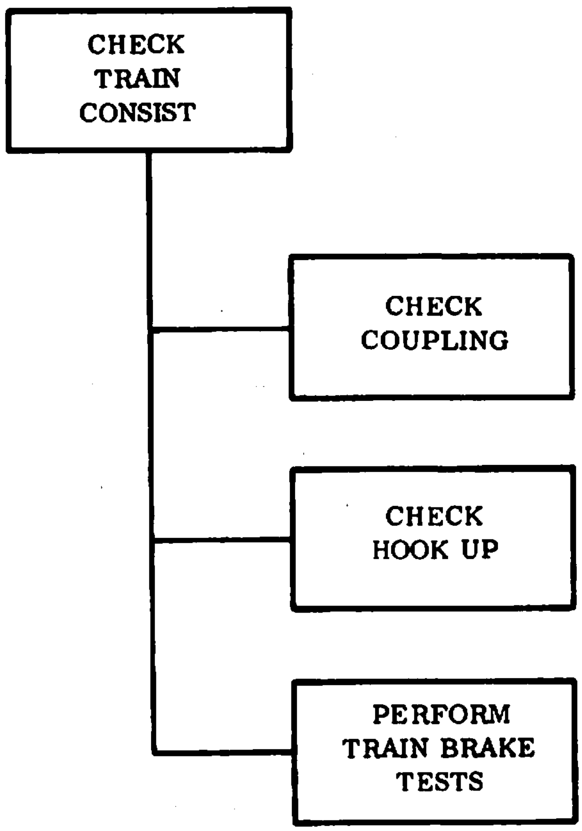

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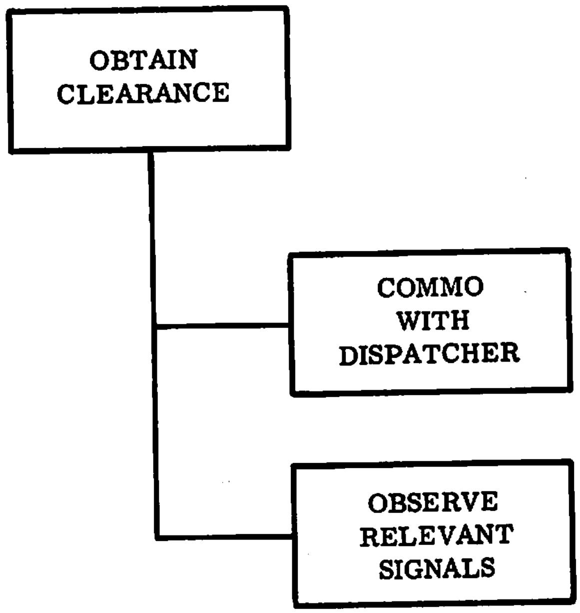

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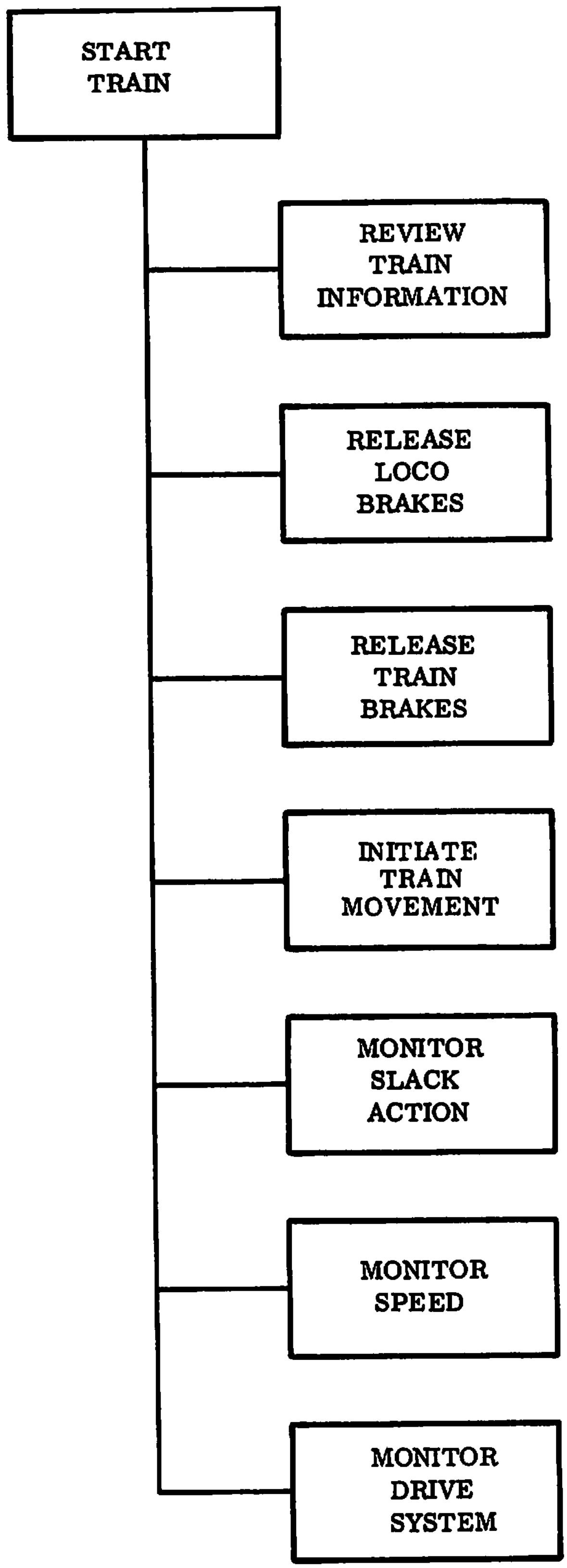

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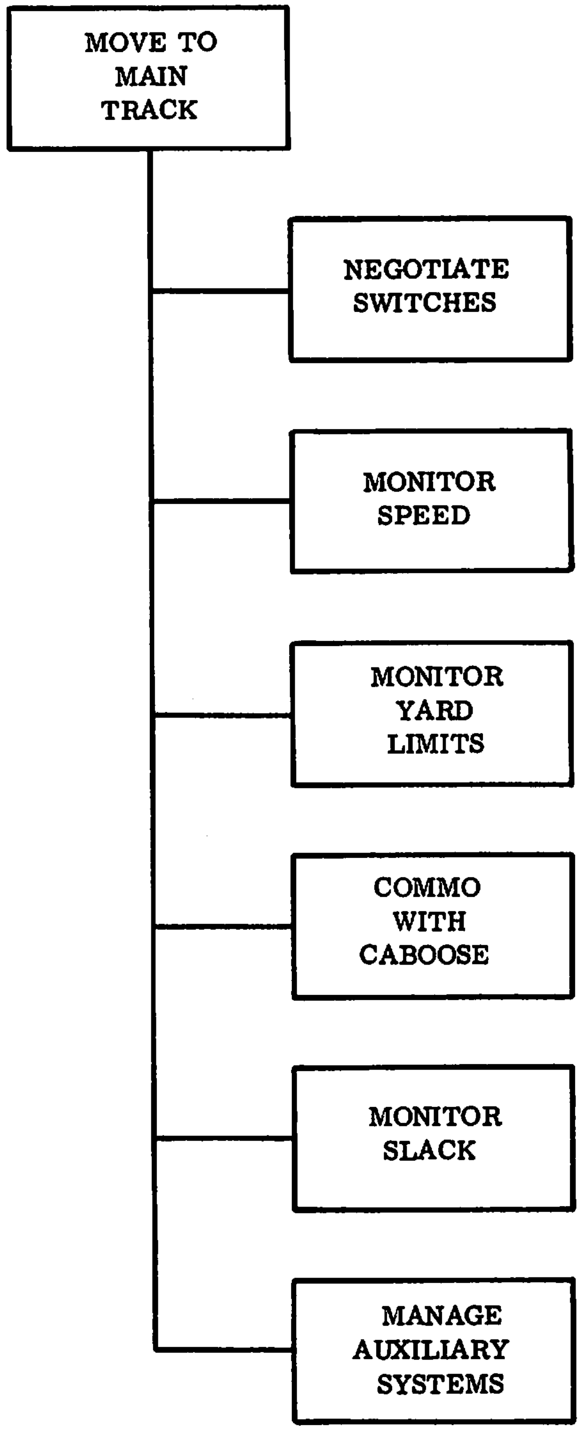

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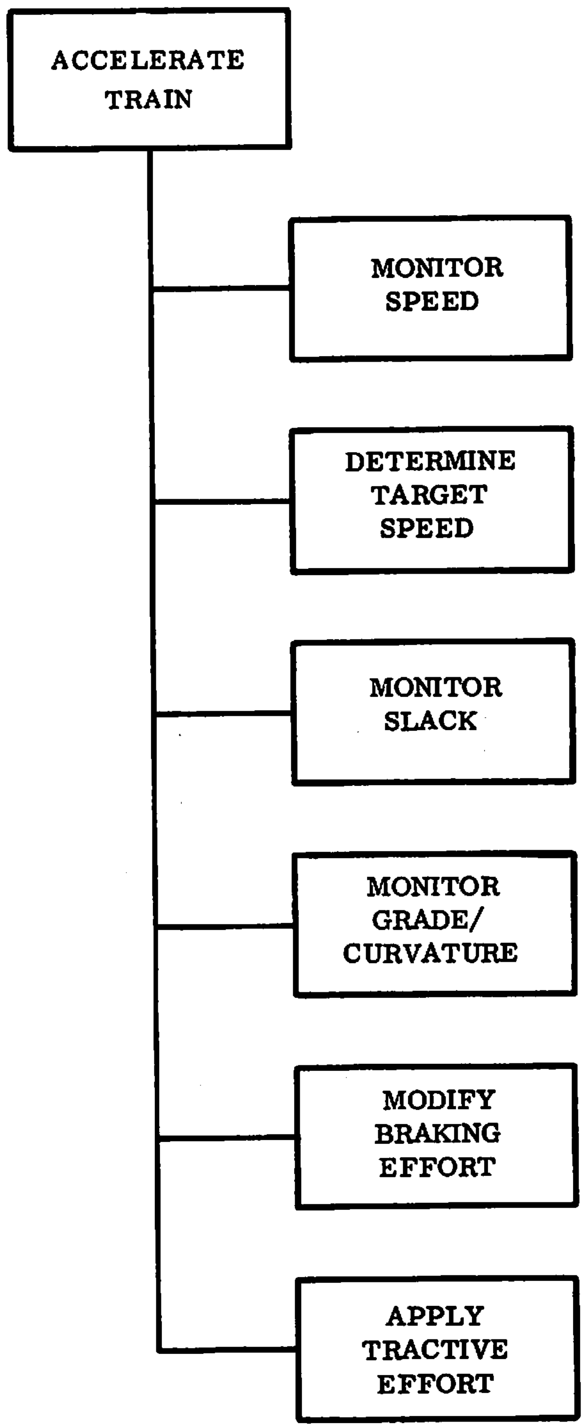

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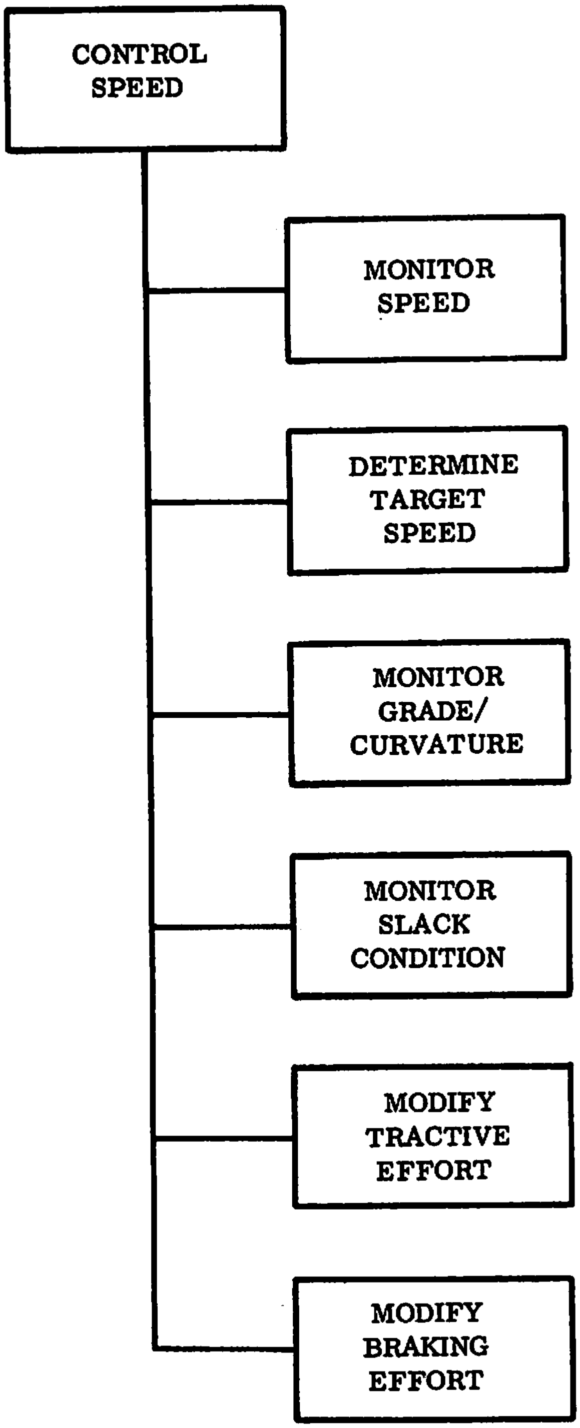

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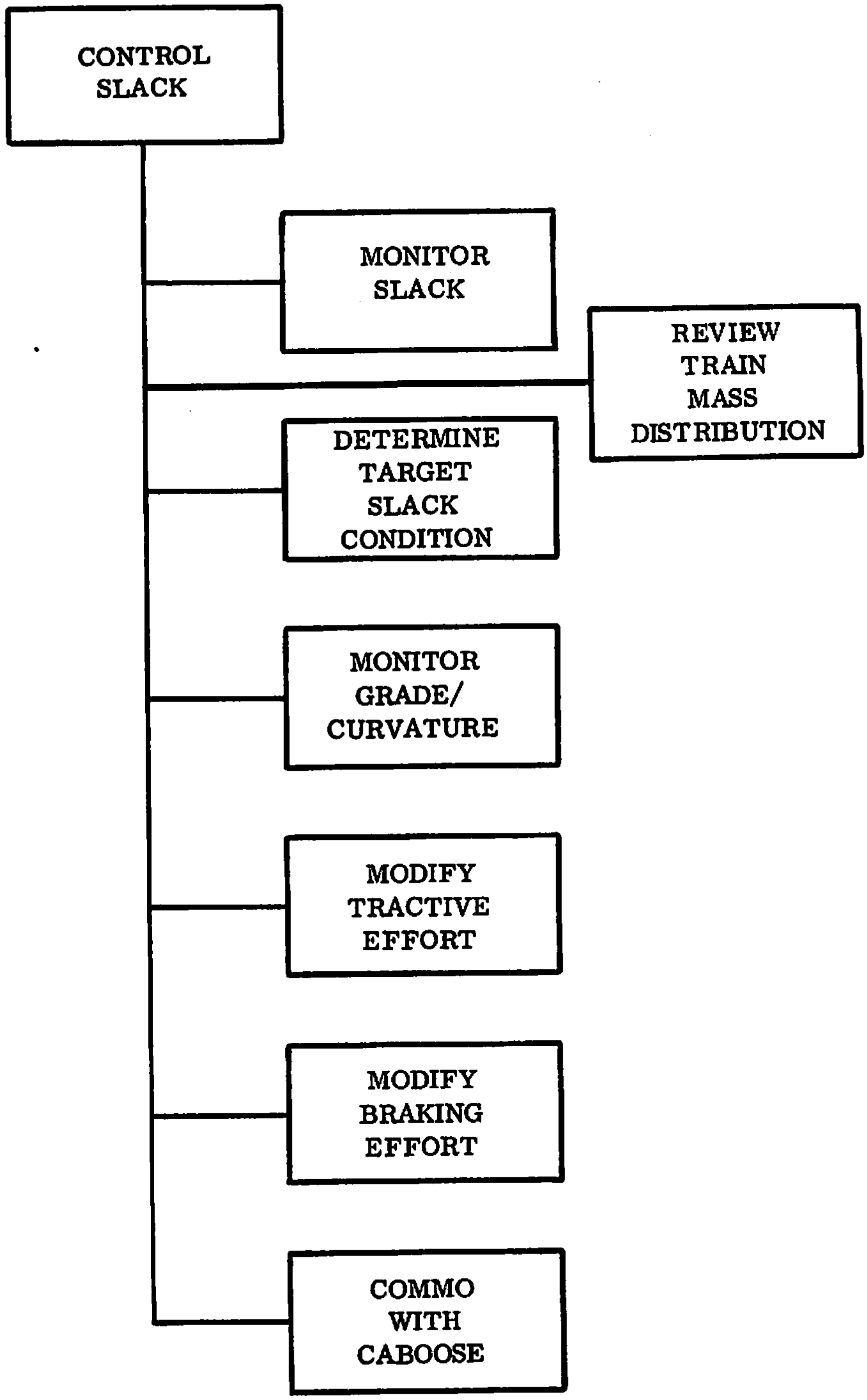

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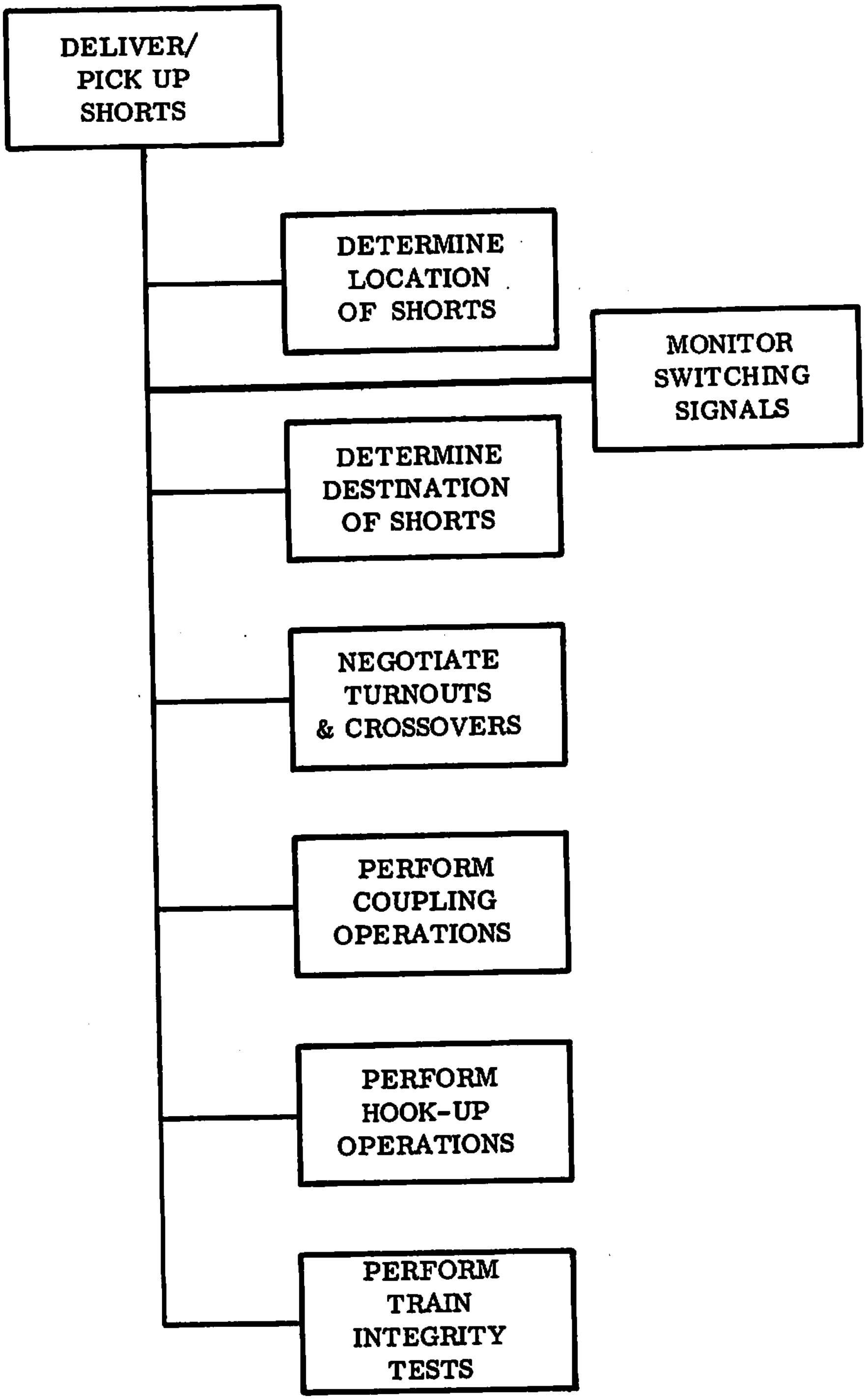

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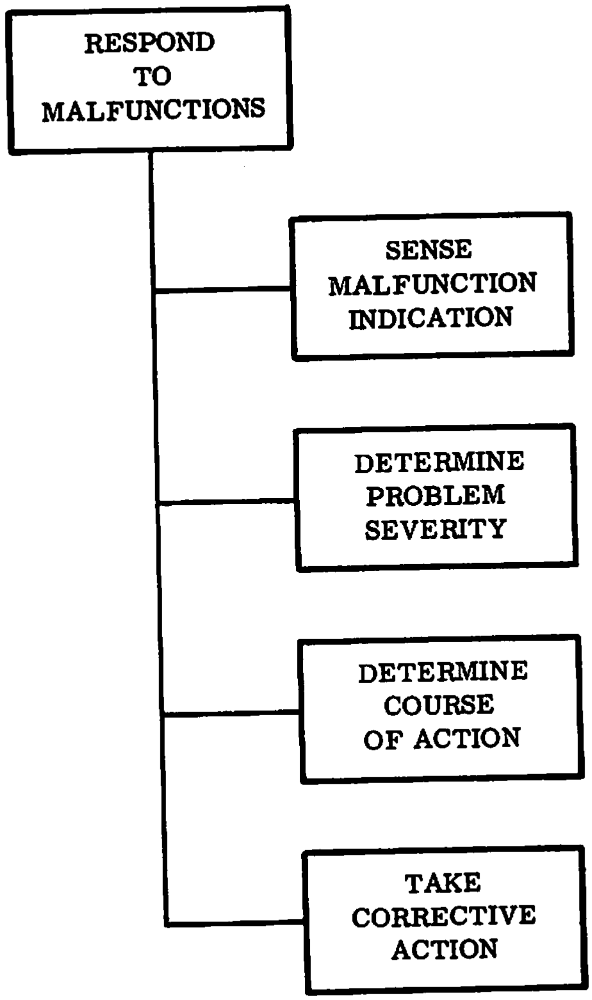

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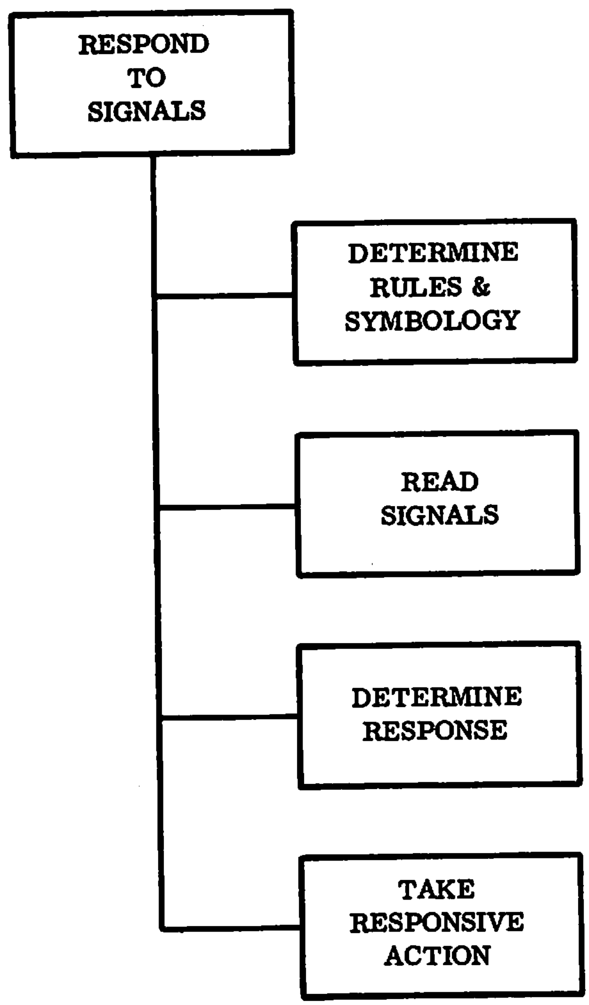

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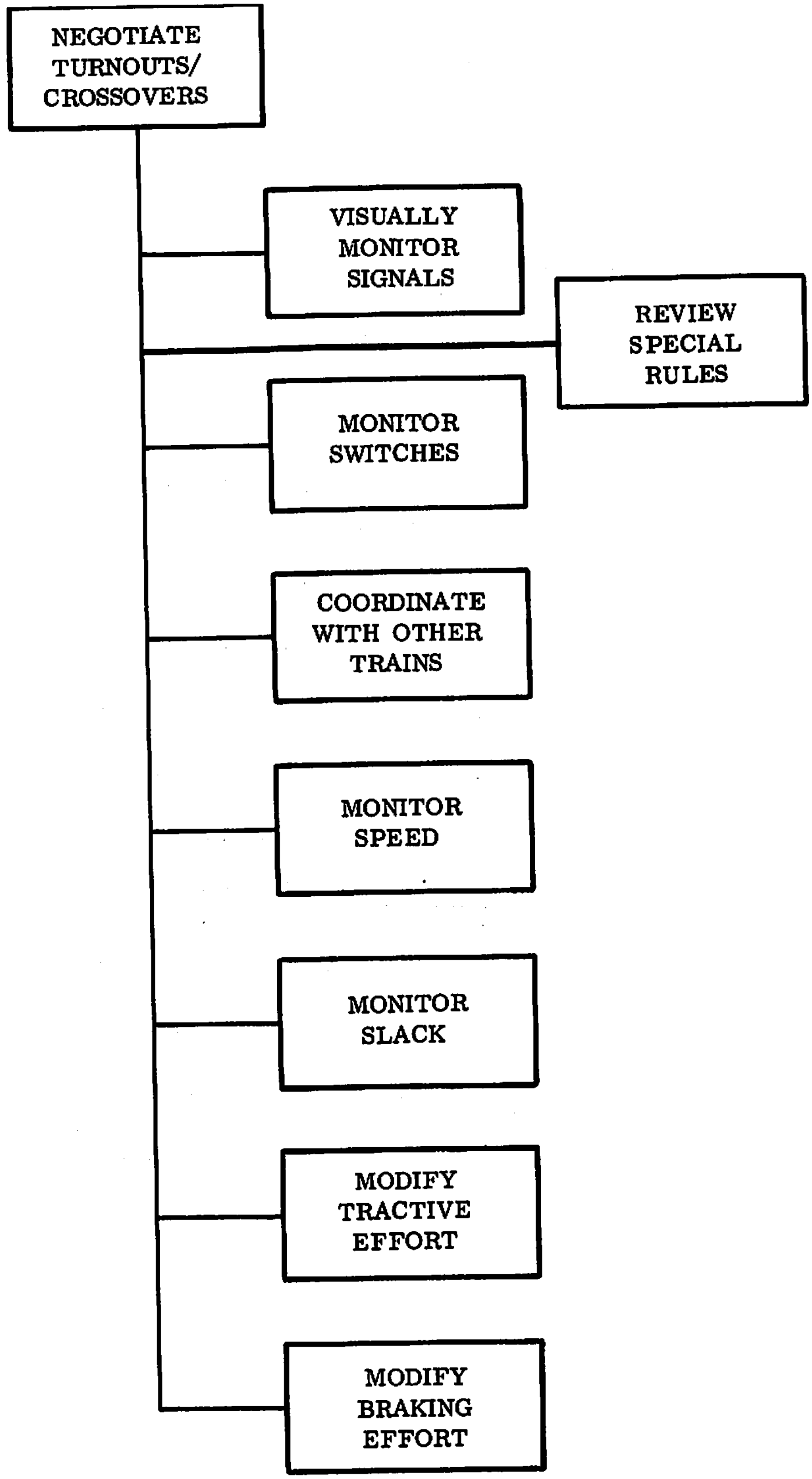

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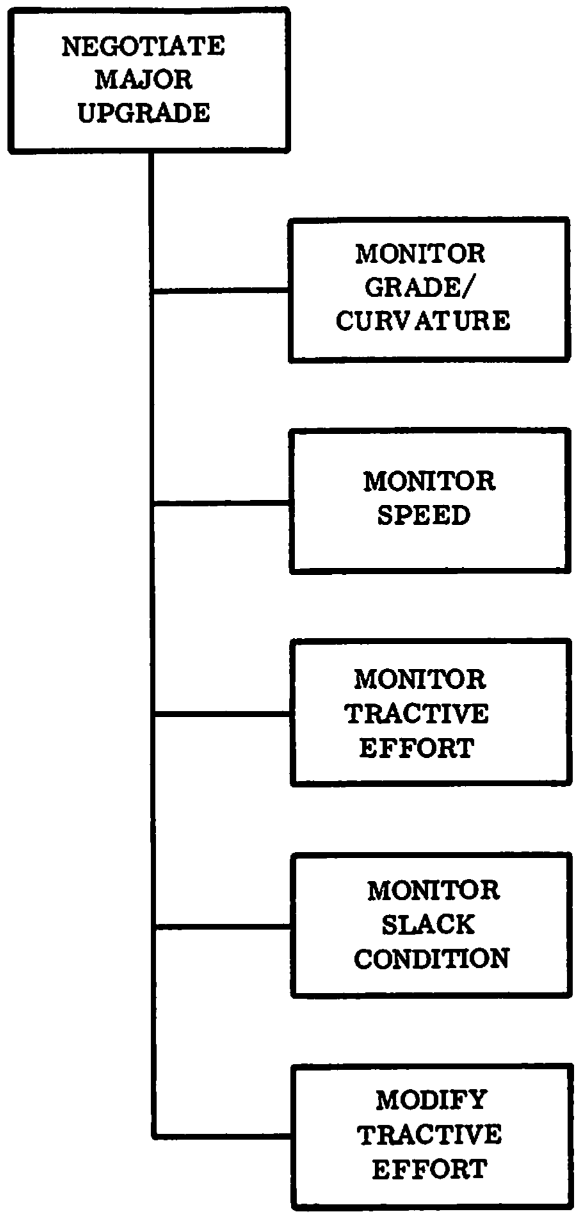

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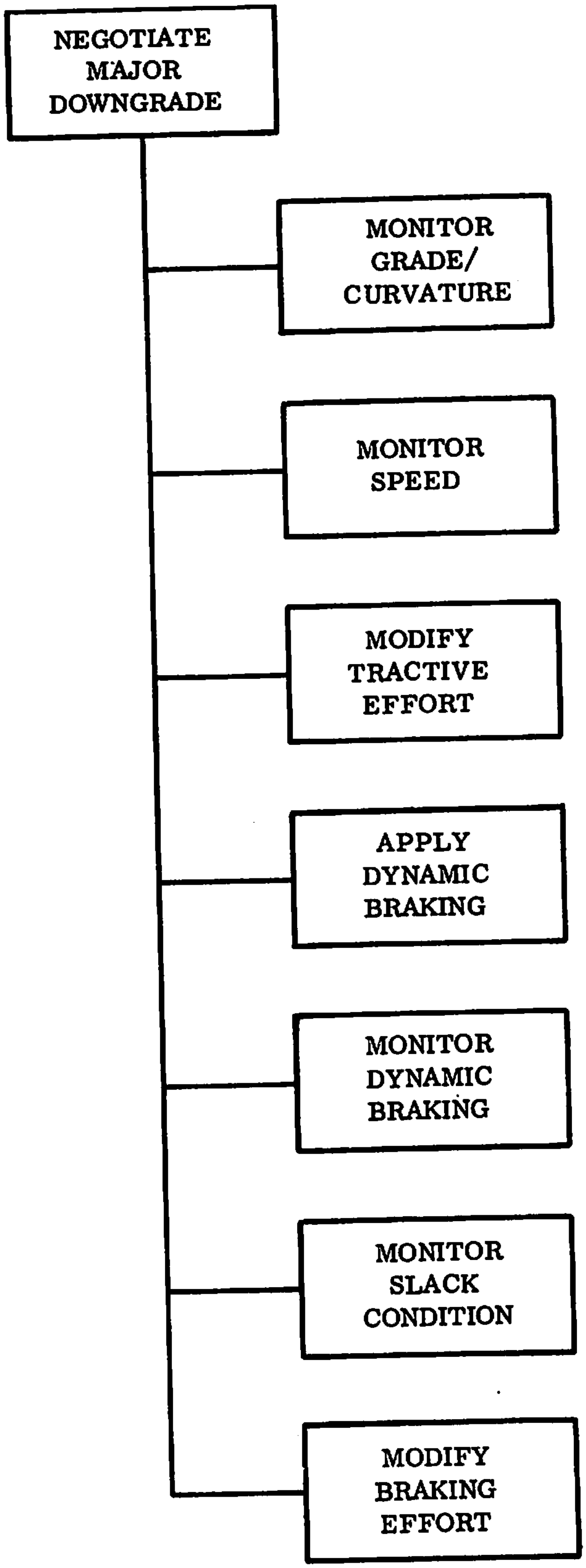

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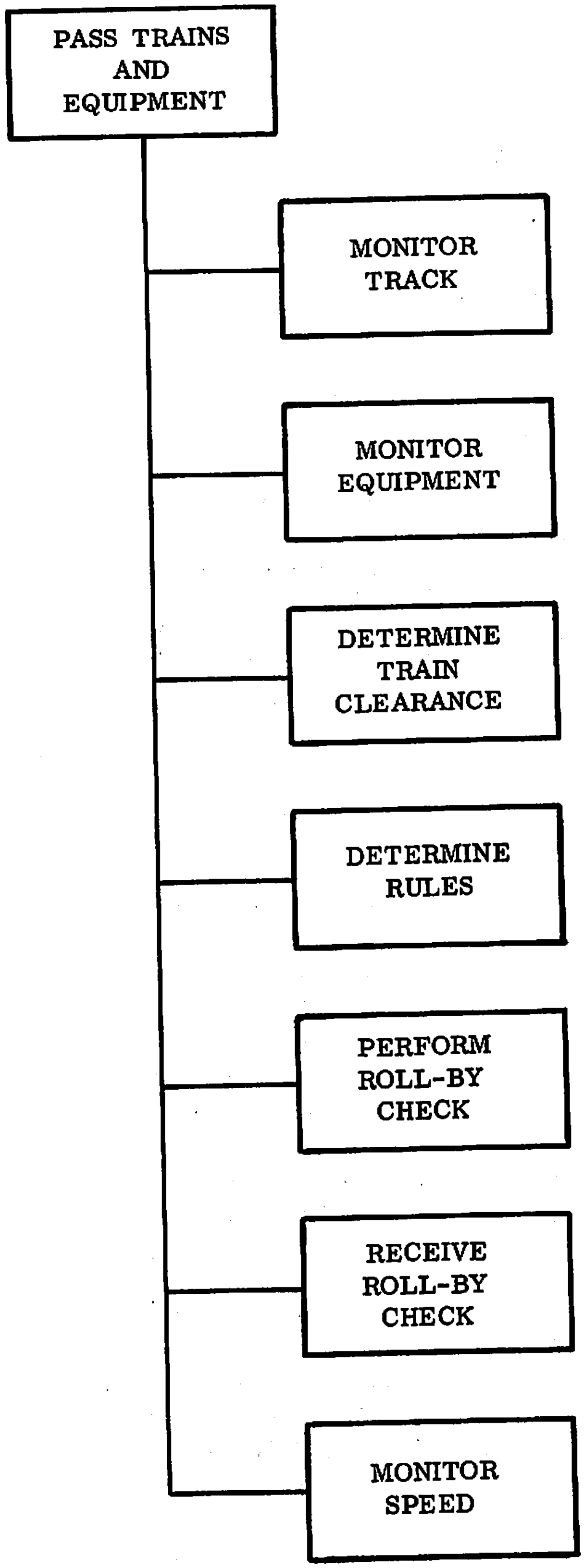

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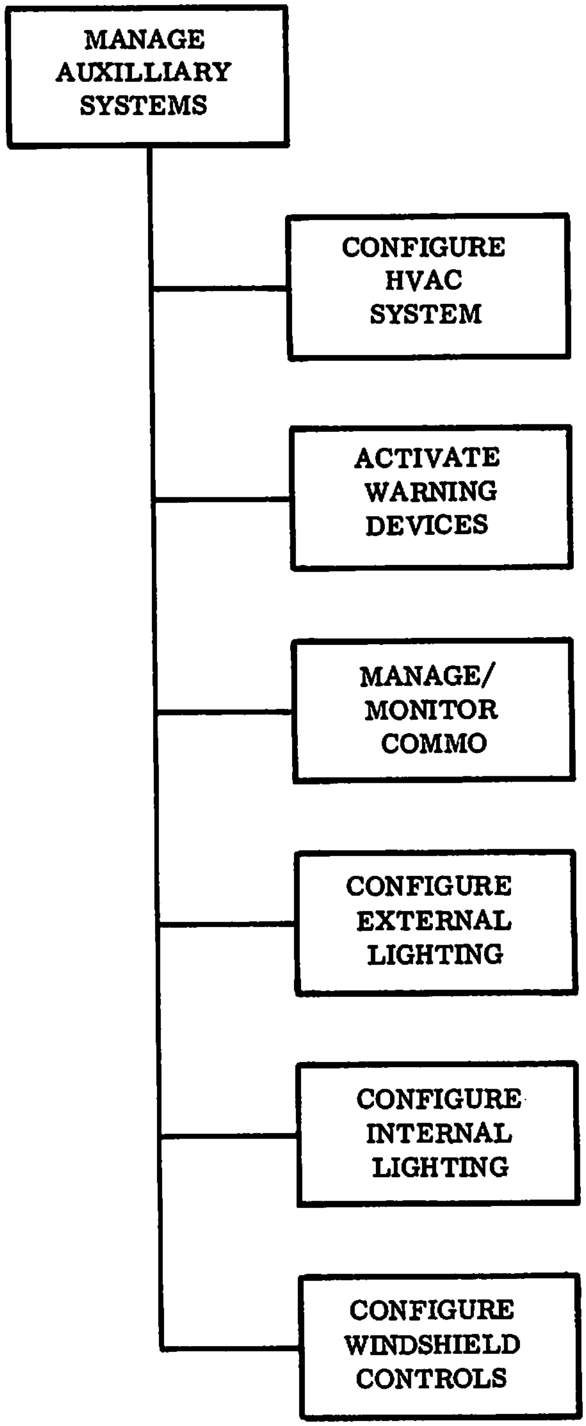

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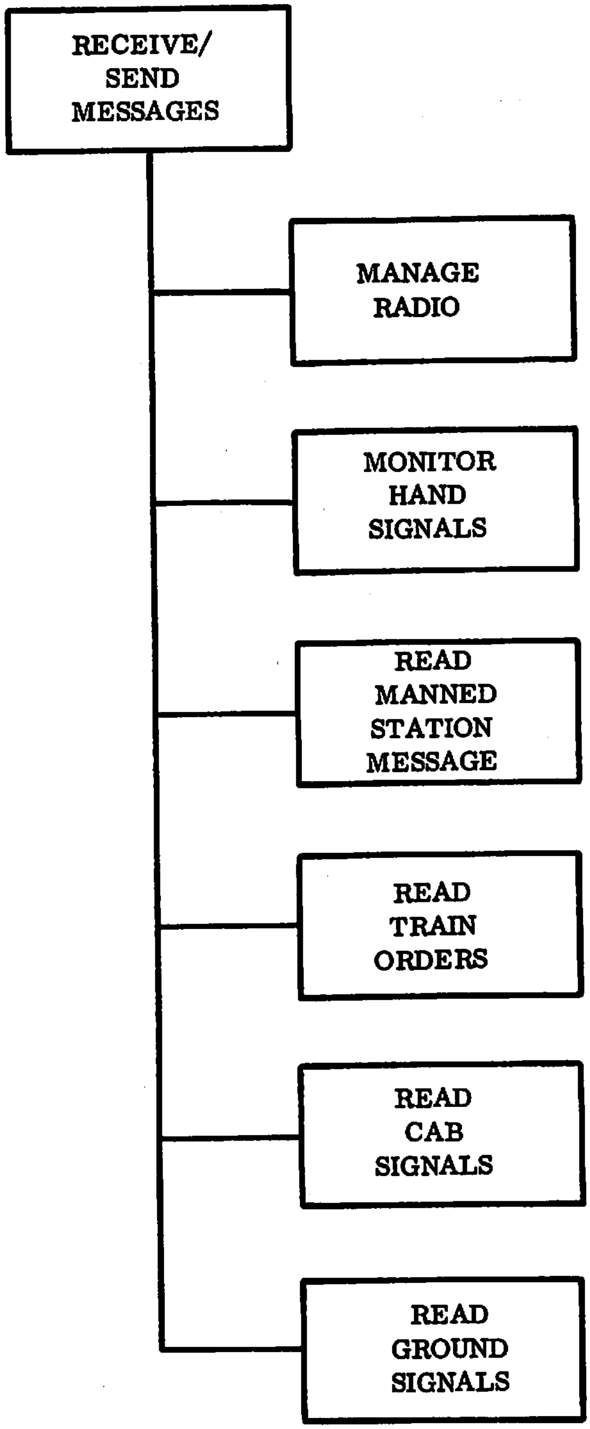

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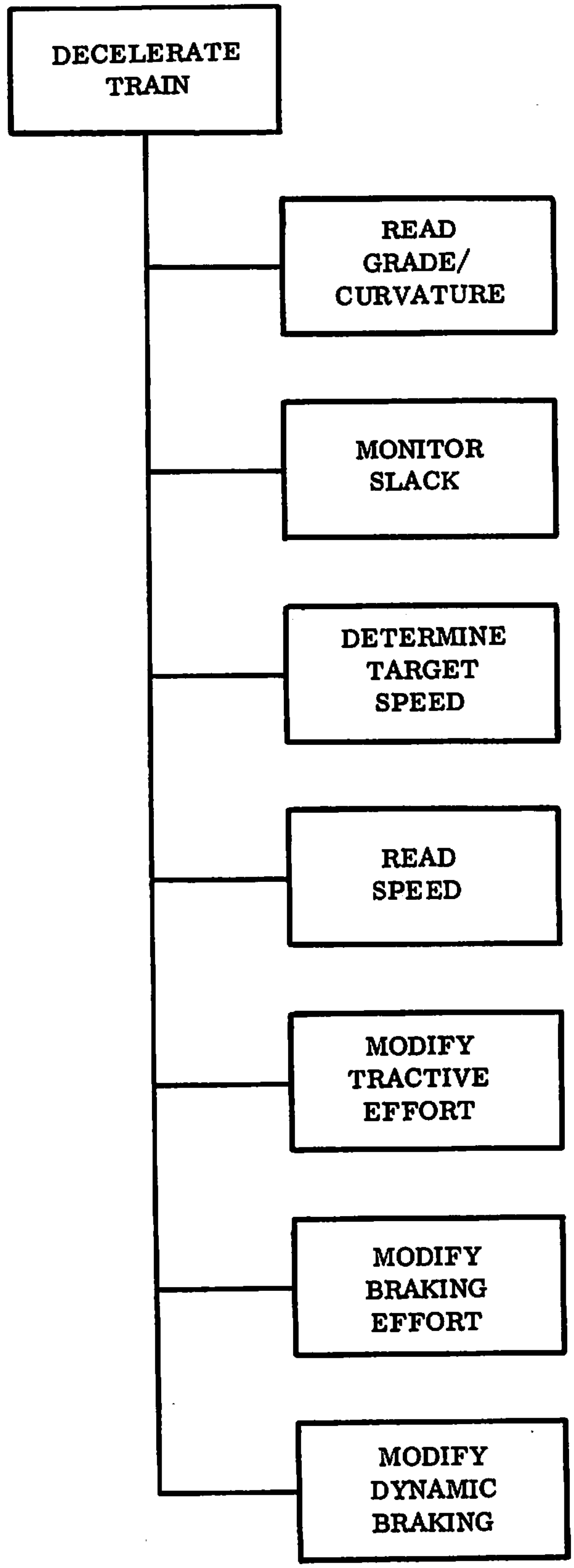

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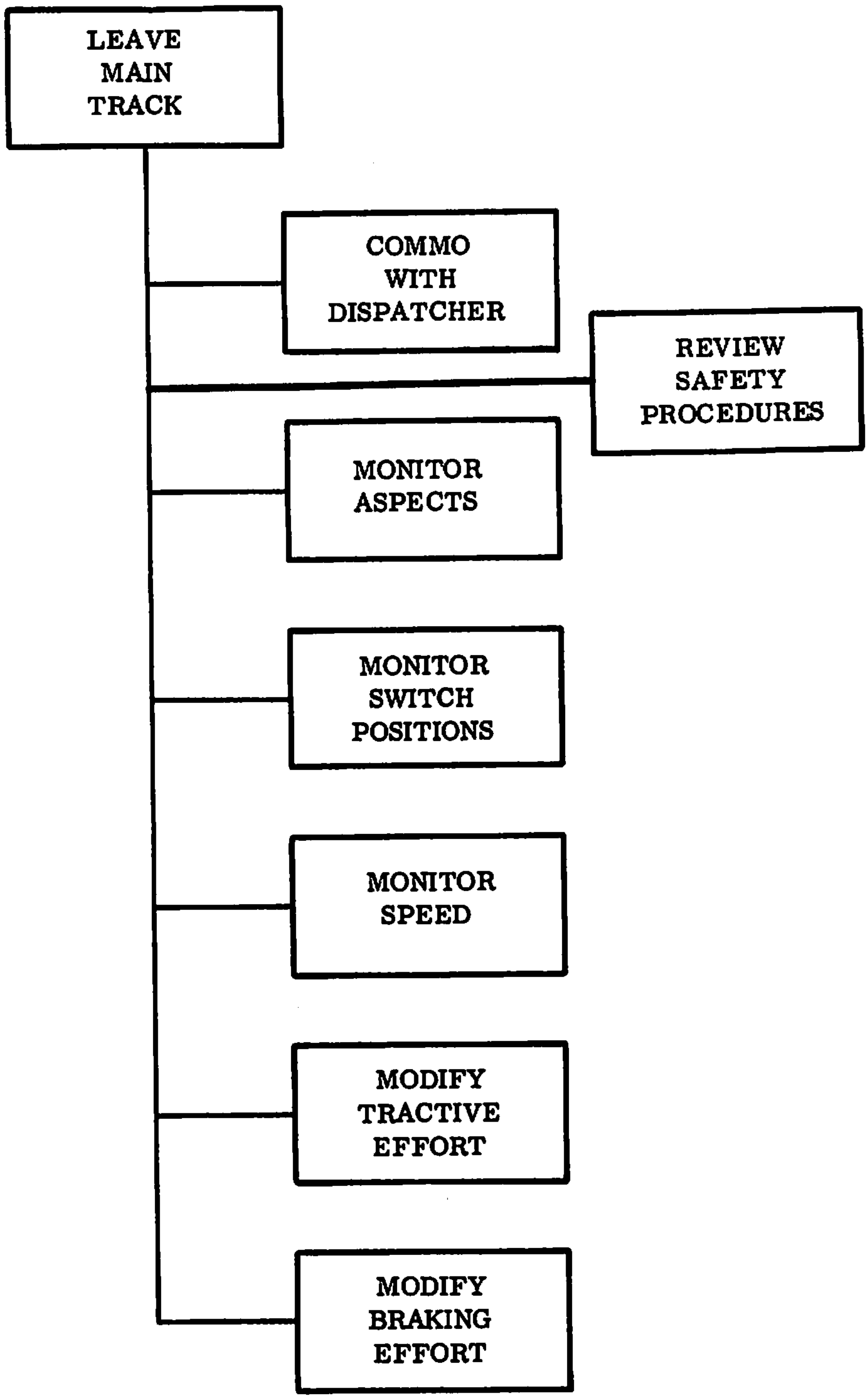

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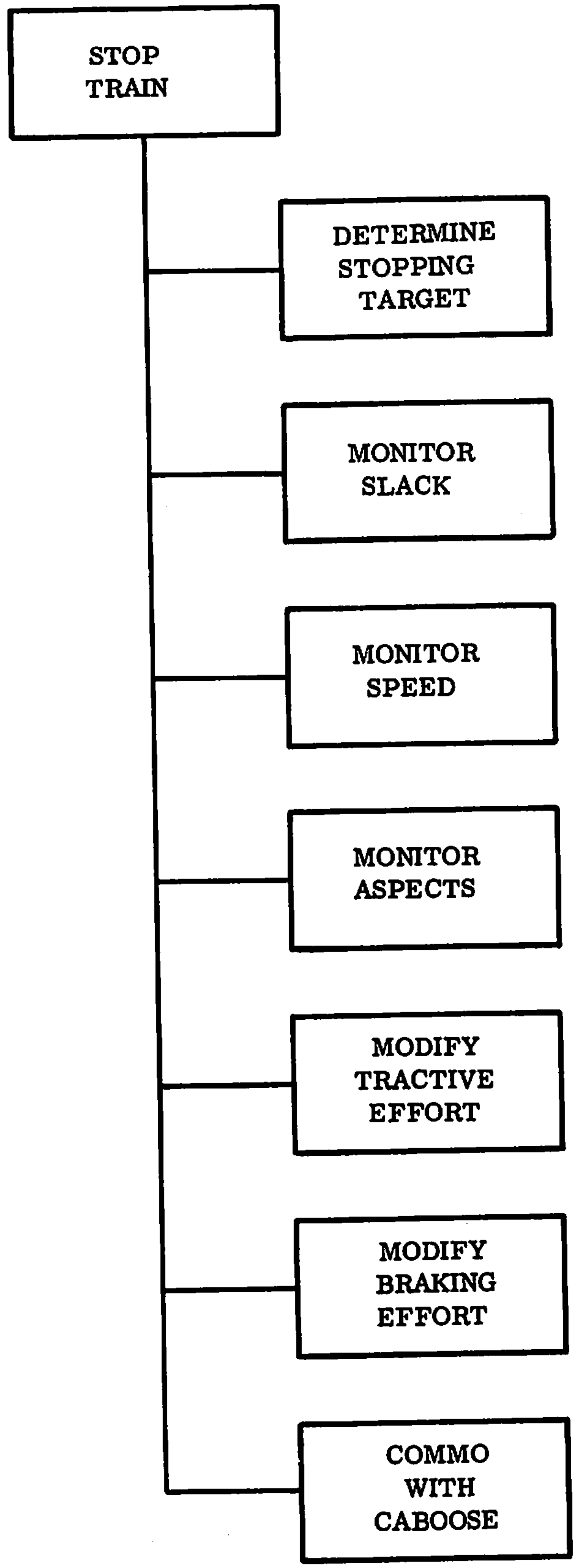

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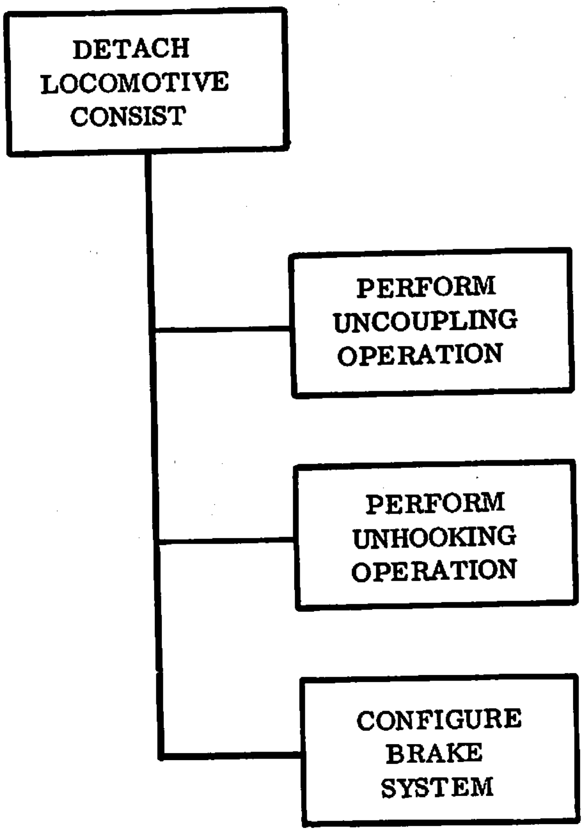

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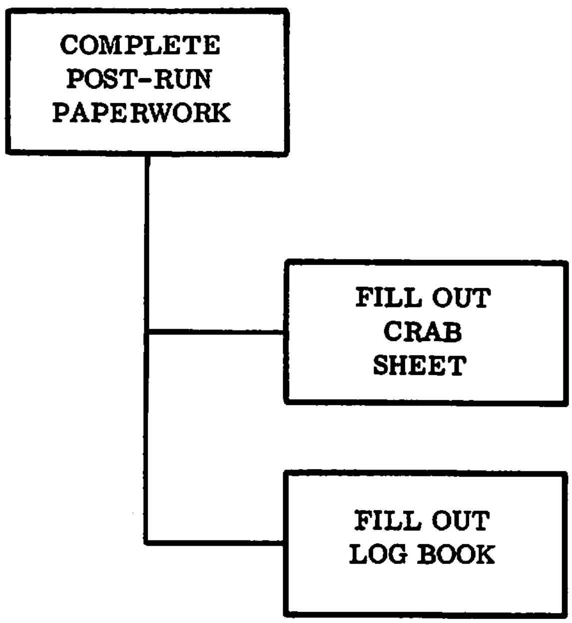

Figure A–1. Level 3 Crew Functions (Continued)

APPENDIX B

INFORMATION/ACTION REQUIREMENTS

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
PERFORM COUPLING OPERATION	Distance to coupler	Window(s)	Apply tractive effort	Throttle	RPM change	RPM indicator
	Loco characteristics	Operator			Speed	Speed indicator
	Grade	Grade indicator			Traction motor load	Traction motor load indicator
			Apply loco brakes	Loco air brake control	Speed	Speed indicator
					Brake cylinder pressure	Brake cylinder pressure indicator
			Monitor hand signals	Window - low angle		
			Check handbrakes	Handbrake		
PERFORM HOOKUP OPERATION	Hose hookup status	Radio	Monitor hand signals	Window		
		Window - low angle	Modify train brake valve	Train air brake control	Brake pipe pressure	Brake pipe pressure indicator
		Coordinate with ground personnel	Monitor radio	Radio		
CHECK DRIVE SYSTEM	Locked wheels	Coordinate with ground personnel	Apply tractive effort	Throttle	Speed	Throttle position speed indicator
	Unusual noises					
	Unusual odors				Malfunction symptoms	Malfunction indicator window
					Wheel slip/slide	Slip/slide indicator
					Traction motor load	Traction motor load indicator
			Apply sand	Sanding control	Sanding	Sanding indicator

Figure B—1. Information and Action Requirements Analysis

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
CHECK PROPULSION SYSTEM	Position of reverser control	Reverser control indicator	Activate generator field	Generator field control	Traction motor load	Traction motor load indicator
	Power on	Power indicator	Set direction of travel	Reverser	Direction of travel	Window
	Engine parameters	Engine readouts	Apply tractive effort	Throttle	Throttle position	Throttle position indicator
	Movement direction	Operator's manual			Traction motor load	Traction motor load indicator
					Speed	Speed indicator
					Traction motor temperature	Traction motor temperature indicator
					Power-Force	Power-Force Display
CHECK COUPLING	Coupler status	Coordinate with ground personnel	Apply tractive effort	Throttle	Throttle position	Throttle position indicator
					Traction motor load	Traction motor load indicator
					Speed	Speed indicator
					Hand signals	Window
			Apply loco air brakes	Loco air brake control	Speed	Speed indicator
					Brake cylinder pressure	Brake cylinder pressure indicator
			Reverse direction of travel	Reverser	Direction of travel	Window

Figure B–1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
CHECK PNEUMATIC SYSTEM	Compressor characteristics	Operator's manual	Read main reservoir pressure	Main reservoir pressure indicator	Compressor safety valve	Compressor safety valve indicator
					Main reservoir pressure change	Main reservoir pressure indicator
			Set direction to neutral	Reverser	Control position	Control
			Race engine	Throttle	Throttle position	Throttle position indicator
					Engine RPM change	RPM indicator
CHECK HOOKUP	Hose status	Window; radio Coordinate with ground personnel	Monitor hand signals	Window	Go/no go	Hand signals
CHECK AUXILIARY SYSTEMS	Locomotive characteristics	Operator's manual	Check radio	Radio controls	Commo check acknowledgment	Radio microphone and speaker
			Check HVAC	HVAC controls	Crew comfort	Crew
			Check internal lighting	Internal lighting controls	Light level	Displays
			Check external lighting	External lighting controls	Light level	External environment
			Check windshield system	Windshield control	Visibility	Windshield
			Check warning devices	Warning device controls	Warning sound	Acoustic environment

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
PERFORM MU TEST	Number of locos	Briefing	Apply tractive effort	Throttle	RPM change in all engines	RPM indicator
	Type locos	Briefing	Release tractive effort	Throttle		
	Are MUs "set in" correctly?	MU control				
CHECK DYNAMIC BRAKE	Range of dynamic brake	Operator's manual	Apply tractive effort	Throttle	Throttle position	Throttle position indicator
					Speed	Speed indicator
					Traction motor load	Traction motor load indicator
	Dynamic brake eration capabilities	Operator's manual	Apply dynamic brake	Dynamic brake control	Speed	Speed indicator
		Training			Dynamic brake load	Dynamic brake indicator
					RPM change	RPM indicator
	Present brake setting	Dynamic brake control position indicator	Set dynamic brake circuit breaker	Dynamic brake circuit breaker	Dynamic brake load	Dynamic brake load indicator
			Set dynamic brake cutout	Dynamic brake cutout control	Dynamic brake action	Dynamic brake indicator
PERFORM LOCO BRAKE TESTS	Brake operation	Coordinate with ground personnel	Apply loco brakes	Independent brake control	Brake cylinder pressure	Brake cylinder pressure indicator
			Release loco brakes	Independent brake control	Hand signals	Window
					Brake cylinder pressure	Brake cylinder pressure indicator
					Pressure venting	Pressure venting indicator
					Hand signals	Window

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
CHECK LOCO BRAKE CONDITION	Locomotive characteristics	Operator's manual	Apply loco air brakes	Loco air brake control	Signal from ground personnel	Window
			Release loco air brakes	Loco air brake control	Signal from ground personnel	Window
PERFORM RUN TEST			Apply tractive effort	Trrottle	Throttle position	Throttle position indicator
	Acceleration rate	Training			Traction motor load	Traction motor load indicator
	Deceleration rate				Speed	Speed indicator
					Hand signals	Window
			Air braking effort	Locomotive air brake control	Brake cylinder pressure	Brake cylinder pressure indicator
					Speed	Speedometer

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
CHECK ENGINE PARAMETERS	Engine characteristics	Operator's manual training				
	Quantity of oil	Oil quantity indicator	Read oil indicator	Low oil indicator		
	Engine temperature	Engine temperature indicator	Read engine temperature	Engine temperature indicator		
	Power status	Power indicator	Read power indicator	Engine power indicator		
	Oil pressure	Oil pressure indicator	Read oil pressure	Oil pressure indicator		
SET UP TRAIN BRAKES	Locomotive characteristics	Operator's manual	Set brake pipe pressure	Feed valve control	Brake pipe pressure	Brake pipe pressure indicator
	Train length	Train mass distribution indicator	Charge train brake system	Throttle	Engine RPM change	RPM indicator
					Compressor action	Brake pipe pressure indicator Compress action indicator

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
PERFORM TRAIN BRAKE TEST	Length of train	Train mass distribution	Charge train brakes	Feed valve	Brake pipe pressure	Brake pipe pressure indicator
	Weather	Briefing			Main reservoir pressure	Main reservoir pressure indicator
	Repeaters	Briefing	Apply train brakes	Train air brake control; Brake pipe pressure indicator	Brake pipe pressure	Brake pipe pressure indicator
	Remote consist location	Briefing				
			Cut air supply	Brake cutoff valve	Brake pipe pressure	Brake pipe pressure indicator
			Check leakage	Brake pipe pressure indicator, air flow indicator clock	Brake air flow	Air flow indicator
			Open air supply	Brake cutoff valve	Brake pipe pressure	Brake pipe pressure indicator
					Brake air flow	Air flow indicator
			Check train brake operation	Radio; window	Hand signals	Window
			Release train brakes	Train air brake control	Brake pipe pressure	Brake pipe pressure indicator
					Equalizer reservoir pressure	Equalizer reservoir pressure indicator
			Communication with caboose	Radio	Brake pipe pressure at caboose	Radio

Figure B–1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
COMMO WITH DISPATCHER	Yard clearance	Visual/auditory communication	Send radio messages	Radio	Radio side tone	Radio
			Receive radio messages	Radio	Acknowledgments	Radio
			Receive written or telephone messages	Wayside telephon	Radio intelligence	Radio
READ SIGNALS	Signal format	Rule book	Read aspects	Window		
			Read hand signals	Window		
			Monitor fuses	Window		
			Monitor torpedoes	Audible signal		
			Read flag signals	Window		
			Read cab signal	Cab signal indicator		
			Read trackside signs	Window		
			Read switch stand signal	Window		

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
REVIEW TRAIN INFORMATION	Shorts/pickups	Briefing	Read slack	Slack indicator		
	Type brake equipment	Inspection	Read grade/curve	Train situated indicator		
	Type bearing	Inspection				
	Length of train	TMD	Read brake pipe pressure	Brake pipe pressure indicator		
	Number of cars	TMD				
	Load vs empties	TMD				
	Special loads	TMD	Read brake cylinder pressure	Brake cylinder pressure indicator		
	Mass distribution	TMD				
	Locomotive mix	Briefing				
RELEASE LOCO BRAKES	Grade/curvature	Grade/curve indicator	Release loco air brakes	Loco air brake control	Brake cyclinder pressure	Brake cylinder pressure indicator
	Status of propulsion system	Traction motor load indicator			Speed	Speed indicator
	Clearance	Dispatcher			Brakes released	Hand signals
	Status of other braking system	Brake pipe pressure				

Figure B–1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
RELEASE TRAIN BRAKES	Grade/curvature	Grade/curve indicator	Release train air brakes	Train air brake control	Brake pipe pressure	Brake pipe pressure indicator
	Weight of cars	Train mass distribution			Equalizer reservoir pressure	Equalizer reservoir pressure indicator
	Status of propulsion system	Load indicator			Main reservoir pressure	Main reservoir pressure indicator
	Clearance	Radio; window				
	Status of other braking systems	Brake cylinder pressure			Speed	Speed indicator
	Slack condition	Slack indicator			Brakes released	Message from caboose

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
INITIATE TRAIN MOVEMENT			Apply tractive effort	Throttle	Throttle position	Throttle position indicator
	Train mass distribution	Train mass distribution graph			Speed	Speedometer
					Traction motor load	Loadmeter
	Loco consist characteristics	Briefing				
					Slack action	Slack indicator
	Type brake equipment	Inspection				
	Slack condition	Slack indicator	Modify tractive effort	Throttle	Throttle position	Throttle position indicator
	Number of cars	Number of cars indicator			Speed	Speedometer
					Traction moto r load	Loadmeter
	Special loads	Special load indicator				
					slack action	Slack indicator
	Grade/curvature	Grade/curve indicator			Commo with caboose	Radio
	Weather	Briefing				
	Direction of movement	Reverser	Apply sand	Sand control	Wheel slip/ slide	Wheel slip indicator
					Sanding	Sanding indicator
	Clearance	Dispatcher				
			Read Power-Force Force	Power-Force Indicator	Drawbar force	Drawbar force indicator

Figure B-1. Information and Action Requirements Analysis (continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
MONITOR SLACK ACTION	Grade/curvature	Grade/curve indicator	Read slack	Slack indicator	Commo with caboose	Radio
	HP available	Operator's manual			Speed	Speed indicator
	Speed	Speedometer			Traction motor load	Load indicator
	Brake system condition	Brake pipe pressure; brake cylinder pressure			Slack action	Slack indicator
	Tractive effort	Loadmeter				
			Read drawbar force	Drawbar force indicator		
MONITOR SPEED	Grade/curvature	Grade/curve indicator	Read speed	Speed indicator		
	Slack condition	Slack indicator	Read speed limits	Window		
	Wheel slip	Wheel slip	Read slack	Slack indicator		
	Train characteristics	TMD	Read traction motor load	Loadmeter		
	Weather	Briefing	Monitor speed rate of can	Speed indicator rate of change indicator		
	Target speed	Briefing Train orders Special orders Wayside signals	Check speed indicator	Timepiece Mile posts		
	Actual speed	Speed indicator				

Figure B–I. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
MONITOR DRIVE SYSTEM	Drive system characteristics	Operator's manual	Read wheel slip/slide	Wheel slip indicator		
			Monitor sanding	Sanding indicator		
			Monitor malfunction indications	Audible sounds Smell Indicator readings		
			Read auto sand	Sanding indicator		
NEGOTIATE SWITCHES	Switch position information	Dispatcher visual	Visually monitor switches	Window	Switch position	Window
	Track/switch condition	Window				
	Speed	Speed indicator	Monitor hand signals	Window		
	Slack condition	Slack indicator				
	Length of train	TMD	Monitor ground signals	Window		
	Special loads	TMD	Monitor cab signals	Cab signals		
	Mass distribution	TMD	Commo with caboose	Radio		

Figure B–1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
MONITOR YARD LIMITS	Length of train	Mass distribution diagram	Read yard limit	Window (track side sign)		
	Yard rules	Rule book				
	Speed	Speed indicator	Monitor speed	Speed indicator		
COMMO WITH CABOOSE	Terrain characteristics	Grade/curve indicator	Receive message from caboose	Radio		
			Acknowledge	Radio		
	Radio procedures	Rule book	Monitor hand signals	Visual		
	Yard clearance	Radio	Acknowledge	Visual		
	Train status	Hand signals				
MONITOR SLACK	Grade/curvature	Train slack indicator	Read slack	Slack indicator		
	Train mass distribution	Mass distribution diagram				
	Speed	Speedometer				
	Drawbar force	Drawbar force indicator				
MANAGE AUXILIARY SYSTEMS	See Function of Appropriate System					
DETERMINE TARGET SPEED	Rules	Rule book	Accelerate train	Throttle Independent brake Train brake		
	Speed limit	Train orders Speed limit signs Ground signals Cab signals Grade/curvature ahead	Decelerate train	Throttle Independent brake Train brake		

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
MONITOR GRADE/ CURVATURE	Grade/curvature	TSI	Read speed limits	Window (track side sign)		
	Track condition	Window	Read grade/ curvature	TSI		
	Weather	Briefing				
	Visibility	Briefing	Observe track condition	Window		
	Special loads	Mass distribution diagram				
	Slack action	Slack indicator				
	Loco characteristics	Operator's manual				
	Train mass distribution	Train mass distribution indicator	Read grade/ curve	Grade/curve indicator		
	Weather	Briefing				
	Track condition	Briefing; window	Visually monitor track	Window		
	Speed	Speed indicator				
	Grade/curve information	Past experience	Mental integration	Training		
	Slack condition	Drawbar readout	Determine brake/ throttle action	Brake pipe pressure indicator; throttle position indicator		

Figure B–1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
MODIFY AIR BRAKING EFFORT	Speed Target speed	Speed indicator Speed sign (window)	Monitor speed Release air brakes	Speed indicator Air brake control	Brake pipe pressure	Brake pipe pressure indicator
	Train mass distribution	Train mass distribution diagram			Equalizer pressure	Equalizer pressure indicator
	Slack condition	Slack indicator			Main reservoir	Main reservoir pressure indicator
	Grade/curvature	Grade/curve indicator				
	Train length	Train mass distribution indicator	Reduce brake pipe pressure	Air brake control	Brake pipe pressure Equalizer pressure Main reservoir pressure Main reservoir pressure	Brake pipe press sure indicator Equalizer pressure indicator Equalizer pressure indicator Main reservoir pressure indicator
					Pressure venting	Pressure venting indicator

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
APPLY TRACTIVE EFFORT	Speed	Speed indicator	Apply tractive effort	Throttle	Throttle position	Throttle position indicator
	Traction motor load	Traction motor load indicator			Traction motor load	Load indicator
					Wheel slip	Speed indicator Slack indicator Wheel slip indicator
	Train mass distribution	Train mass distribution indicator	Awareness of mass distribution	Train mass distribution indicator		
	Grade	Grade indicator	Monitor speed	Speed indicator		
			Rate of change	Speed rate indicator		
	Slack condition	Slack indicator	Read drawbar force	Drawbar force indicator		
	Track condition	Briefing	Awareness of track condition	Visual		
MODIFY TRACTIVE EFFORT	Speed	Speed indicator	Monitor speed	Speed indicator		
	Traction motor load	Loadmeter	Modify tractive effort	Throttle	Throttle position Traction motor load Speed Slack Wheel slip	Throttle position indicator Load indicator Speed indicator Slack indicator Wheel slip indicator
	Train mass distribution	Train mass distribution indicator	Awareness of grade	Grade indicator		
	Grade	Grade indicator	Read drawbar indicator	Drawbar force indicator		
	Slack condition	Slack indicator				
	Track condition	Briefing	Awareness			

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
REVIEW TRAIN MASS DISTRIBUTION	Locomotive consist characteristics	Operator's manual	Read train mass distribution	Train mass distribution indicator		
	Train makeup	Train mass distribution indicator				
DETERMINE TARGET SLACK CONDITION	Locomotive consist characteristics	Operator's manual	Read train mass distribution	Train mass distribution indicator		
	Train handling rules	Rule Book Educational bulletin	Read slack condition	Slack indicator		
			Read grade/ curvature	Grade/curve indicator		
			Read speed	Speed indicator		
			Read traction motor load	Traction motor load indicator		
			Read throttle position	Throttle position indicator		
			Read brake pipe pressure	Brake pipe pressure indicator		
			Read dynamic brake condition	Dynamic brake indicator		
DETERMINE LOCATION OF SHORTS	Train order format	Rule book	Read train mass distribution	Train mass distribution indicator		
MONITOR SWITCHING SIGNALS	Operating rules	Rule book	Read signals	Window		
	Signal symbology	Rule book	Read switch position	Window		

Figure B–1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
DETERMINE DESTINATION OF SHORTS	Train order format	Rule book	Read destination of shorts	Train orders		
NEGOTIATE TURNOUTS/CROSSOVERS	Speed	Speed indicator	Visually monitor switches	Window		
	Grade/curvature	Grace/curve indicator				
	Train mass distribution	Train mass distribution indicator	Visually monitor signals	Window		
	Timetable	RR timetable				
	Right	Train order	Receive/send messages to other trains	Radio	Acknowledgment from other end	Radio
	Class	Train order				
	Direction	Train order				
	Directions from dispatcher	Radio				
	Switch condition	Window	Monitor speed	Speed indicator		
	Restrictive speed limit	Train order, speed sign	Monitor speed	Slack indicator		
			Modify tractive effort	Throttle	Throttle position Speed Traction motor load	Throttle position indicator Speed indicator Traction motor load indicator
			Modify air braking effort	Air brake control	Speed Brake pipe pressure Equalizer reservoir pressure	Speed indicator Brake pipe pressure indicator Equalizer reservoir pressure indicator
			Read cab signals	Cab signal indicator		
			Monitor own train	Window		

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
PERFORM TRAIN INTEGRITY TESTS	Train length	Train mass distribution indicator	Release train brakes	Train brake control	Brake pipe pressure	Brake pipe pressure indicator
					Commo from caboose	Radio
			Apply tractive effort	Throttle	Throttle position	Throttle position indicator
					Traction motor load	Traction motor load indicator
					Speed	Speed indicator
					Commo from caboose	Radio
SENSE MALFUNCTION INDICATION			Read annunciator	Annunciator panel		
	Train operational characteristics	Operator's manual	Monitor alarm	Alarm		
	Effects of malfunctions on performance	Training	Monitor malfunction source	Malfunction		
DETERMINE PROBLEM SEVERITY	Problem symptoms	Indicators Sounds Smells Visual inspection	Review rules	Rule book		
			Review RR directive	RR publication		
			Make go/no go decision	Rule book		

Figure B–1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
DETERMINE COURSE OF ACTION	Problem severity	Problem symptoms	Review rules	Rule book		
			Review RR directives	RR publication		
TAKE CORRECTIVE ACTION	Course of action previously determined	Problem severity	Continue trip	---		
			Stop train	Throttle Brake controls		
DETERMINE RULES AND SYMBOLOGY	Rule and symbology format	Rule book	Read rules and symbology of signals	Rule book		
DETERMINE RESPONSE (TO SIGNALS)	Operating rules	Rule book	Read signal	Window Audible signal Cab signal indicator		
			Evaluate train condition	Speed indicator		
				Traction motor load indicator		
				Brake pipe pressure indicator		
				Dynamic brake indicator		
				Grade/curve indicator		
			Review signal meaning	Rule book		

Figure B–1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
TAKE RESPONSIVE ACTION (TO SIGNALS)	SIGNALS PRESENTED	Previously determined	Continue present action			
			Increase speed	Throttle	Throttle position Speed	Throttle position indicator Speed indicator
				Train brake control	Traction motor load Brake pipe pressure Speed	Traction motor load indicator Brake pipe pressure indicator Speed indicator
			Decrease speed	Throttle	Throttle position Speed Traction motor load	Throttle position indicator Speed indicator Traction motor load indicator
				Train brake control	Brake pipe pressure Speed	Brake pipe presure indicator Speed indicator
			Stop train	Throttle	Throttle position Speed Traction motor load	Throttle position indicator Speed indicator Traction motor load indicator
			Initiate emergency procedure	Train brake control	Brake pipe pressure Speed	Brake pipe pressure indicator Speed indicator
				Train brake control	Brake pipe pressure Speed Air flow	Brake pipe pressure indicator Speed indicator Air flow indicator
				Emergency control	Brake pipe pressure Air flow	Brake pipe pressure indicator Air flow indicator

Figure B–1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
VISUALLY MONITOR SIGNALS	See "Read Signals"					
REVIEW SPECIAL RULES	Train direction Train class Train right Train number	Train orders	Read train orders	Train orders		
			Read rule book	Rule book		
MONITOR SWITCHES	Switch stand symbology	Rule book	Read switch signal	Window		
			Monitor switch points	Window		
COORDINATE WITH OTHER TRAINS	Train orders	Train orders	Send message	Radio Headlight Horn Hand signal		
	Timetable	Timetable				
			Receive message	Radio Window		
APPLY MODIFY DYNAMIC BRAKING	Dynamic brake range	Operator's manual	Apply dynamic braking	Dynamic brake control	Dynamic brake load	Dynamic brake indicator
	Speed	Speed indicator			Speed	Speed indicator
	Slack condition	Slack indicator			Slack	Slack indicator
	Train characteristics	Train mass distribution				
	Grace/curvature	Grace/curve indicator	Release dynamic braking	Dynamic brake control	Dynamic brake load	Dynamic brake indicator
					Speed	Speed indicator
	Target speed	Speed limit			Slack	Slack indicator

Figure B–1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
MONITOR DYNAMIC BRAKING	Dynamic brake type	Operator's manual	Read dynamic braking effort	Dynamic brake indicator		
	Locomotive characteristics	Operator's manual	Read speed	Speed indicator		
	Train mass distribution	Train mass distribution display				
	Grade/curvature	Grade/curve indicator				
MONITOR TRACK	Weather	Briefing	Monitor track condition	Window		
	Speed	Speed indicator				
MONITOR TRACK-SIDE EQUIPMENT	Train orders	Train orders	Monitor track-side equipment	Window		
DETERMINE TRAIN CLEARANCE	Review train characteristics for high/wide load	High/wide load display	Monitor track-side clearance	Window		
DETERMINE RULES	See "Review Special Rules"					
PERFORM ROLL-BY CHECK	Speed	Speed indicator	Monitor other train	Window		
	Whether train being checked is "good or bad"	Visual	Transmit message to other train	Radio	Acknowledgment	Radio

Figure B–1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
RECEIVE ROLL-BY CHECK	Indication from inspection that check is being performed	Hand signal or radio	Receive message from inspector	Radio or visual		
			Acknowledgment	Radio or visual		
CONFIGURE HEATING/VENTILATION/AIR CONDITIONING SYSTEM	Cab comfort	Crew comfort judgment	Control temperature	Temperature control	Temperature	Crew comfort
			Control venting	Window	Air flow	Crew comfort
ACTIVATE WARNING DEVICES	Rules	Rule book	Sound horn	Horn control	Horn sound	
			Sound bell	Bell control	Bell sound	
MANAGE/MONITOR COMMUNCIATIONS	Radio procedures Radio characteristics	Rule book Operator's manual	Send radio message	Radio	Acknowledgment	
	Need for communication	Rules	Receive radio message	Radio		
	Previous communications		Sound horn	Horn control	Whistle sound	
			Monitor hand signals	Window		
			Read written messages	Wayside pickup		
			Send/receive telephone messages	Wayside telephone	Acknowledgment	Radio

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
CONFIGURE EXTERNAL LIGHTING	Rules Train class	Rule book Train orders	Illuminate train	Headlight control	Increased visibility	Window
			Display train class	Class light control		
			Display numbers	Number light control		
			Illuminate exterior steps, walkways, etc.	External auxiliary light control	Increased visibility	Window
CONFIGURE INTERNAL LIGHTING	Ambient light	Visual	Illuminate panel	Panel light control	Legibility of panel	Lighted displays
			Illuminate instruments	Instrument light control	Legibility of instruments	Lighted instruments
			Illuminate cabin	Cabin light control	Cabin illumination	Cabin environment
			Use auxiliary internal illumination	Internal auxiliary light control	Auxiliary illumination	Cabin environment
			Use emergency internal illumination	Emergency light control	Emergency illumination	Cabin environment
CONFIGURE WINDSHIELD CONTROLS	Weather	Briefing	Defog windshield	Defogger control	Increased visibility	Windshield
	Visibility	Window	Wipe windshield	Wiper control	Increased visibility	Windshield
			Wash windshield	Washer control	Increased visibility	Windshield

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
MANAGE RADIO	See "Manage/Monitor Communications"					
MONITOR HAND SIGNALS	See "Manage/Monitor Communications"					
READ MANNED STATION MESSAGE	See "Manage/Monitor Communications"					
READ TRAIN ORDERS	Train order interpretation	Rule book	Read train orders	Train orders		
READ CAB SIGNALS	See "Read Signals"					
REVIEW SAFETY PROCEDURES	Railroad rules	Rule book	Read safety rules	Rule book		
OBSERVE SIGNALS/ ASPECTS	Signal symbology	Rule book	Monitor signals/ aspects	Window		

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
DETERMINE STOPPING TARGET	Train mass distribution	Train mass distribution display				
	Speed	Speed indicator				
	Tractive effort	Traction motor load				
		Throttle position				
	Dynamic braking effort	Dynamic brake indicator				
		Dynamic brake control position				
	Air braking effort	Brake pipe pressure indicator				
	Stop signal	Window				
PERFORM UNCOUPLING OPERATION	Locomotive characteristics	Operator's manual	Apply tractive effort	Throttle	RPM change	RPM indicator
					Traction motor load	Traction motor load indicator
	Grade	Grade indication				
	Train is uncoupled	Hand signals			Speed	Speed indicator
					Throttle position	Throttle position indicator
			Apply loco brake	Loco air brake control	Speed	Speed indicator
					Brake	Brake cylinder
					Cylinder pressure	Pressure indicator
			Monitor hand signals	Window		

Figure B—1. Information and Action Requirements Analysis (Continued)

FUNCTION	INFORMATION		ACTION		FEEDBACK	
	TYPE	SOURCE	TYPE	SOURCE	TYPE	SOURCE
PERFORM UNHOOKING OPERATIONS	Coordinate with ground personnel	Radio Window	Monitor hand signals	Window		
	Train is unhooked	Hand signals				
CONFIGURE BRAKE SYSTEM	Rules of operating property	Rule book	Set hand brakes	Hand brake	Brake condition	Ground personnel
	Grade	Train handling indicator	Set loco brakes	Independent brake control		
			Set train brakes	Train brake control		

Figure B–1. Information and Action Requirements Analysis (Continued)

APPENDIX C

REPORT OF INVENTIONS

During the course of this project no innovations, discoveries, or inventions were made. The study has, however, applied state-of-the-art human engineering system principles and design practices to develop an improved freight locomotive cab.

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