R. Scharr

Bolt Beranek and Newman Inc.

7301

Program Review

Braking and Coupling Systems Design Optimization

January 1979

Presented to:
Federal Railroad Administration

Program Review

BRAKING AND COUPLING SYSTEMS DESIGN OPTIMIZATION

FRA Contract No. DOT-FR-8091

January 1979

Presented by:

Bolt Beranek and Newman Inc.
Cambridge, MA 02138

Presented to:

Federal Railroad Administration
Washington, DC 20590

DISCLAIMER

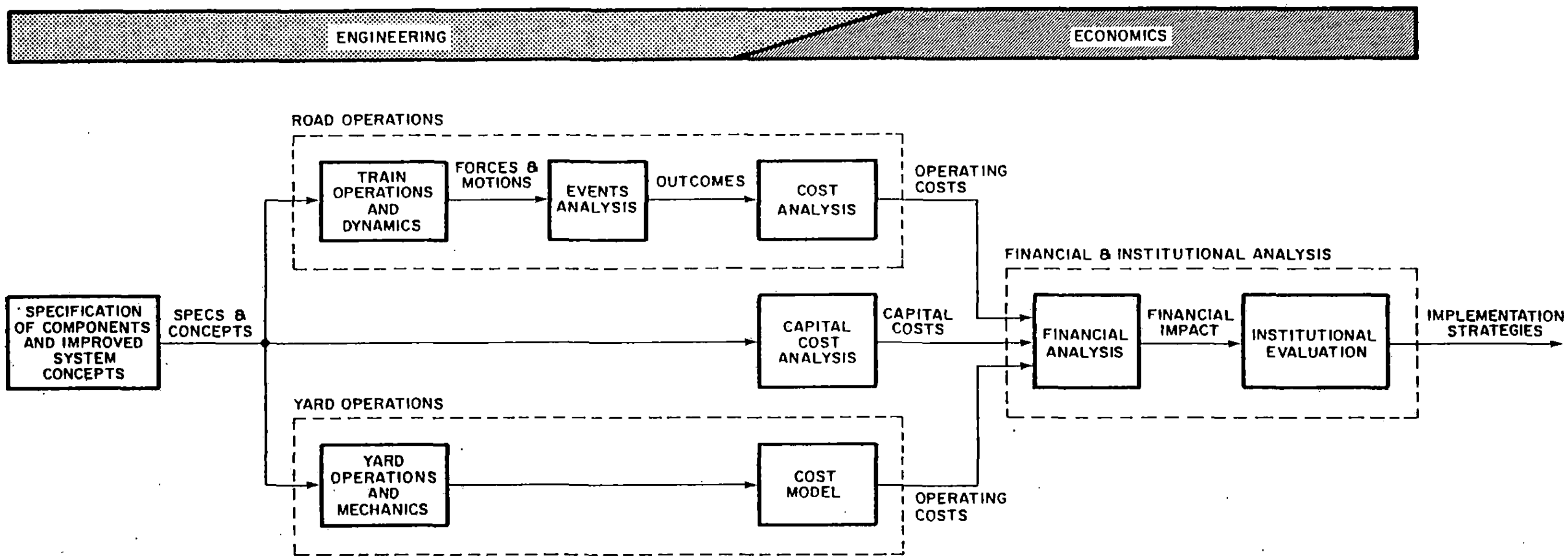
BRAKING AND COUPLING PROGRAM REVIEW
4 JANUARY 1979

- Program Background and Objectives
- Program Review
  - Methodology and Data Base
  - Existing Equipment
  - Innovative Concepts
- Additional Discussion

PROGRAM OBJECTIVES

- Advanced Braking and Coupling Concept Development and Evaluation to Increase Railroad Profitability
- An R & D Plan for the Development and Implementation of Advanced Braking and Coupling Systems

OVERVIEW


ENGINEERING
ECONOMICS
ROAD OPERATIONS
TRAIN OPERATIONS AND DYNAMICS
FORCES & MOTIONS
EVENTS ANALYSIS
OUTCOMES
COST ANALYSIS
OPERATING COSTS
SPECIFICATION OF COMPONENTS AND IMPROVED SYSTEM CONCEPTS
SPECS & CONCEPTS
CAPITAL COST ANALYSIS
CAPITAL COSTS
FINANCIAL & INSTITUTIONAL ANALYSIS
FINANCIAL ANALYSIS
FINANCIAL IMPACT
INSTITUTIONAL EVALUATION
IMPLEMENTATION STRATEGIES
YARD OPERATIONS
YARD OPERATIONS AND MECHANICS
COST MODEL
OPERATING COSTS

BIBLIOGRAPHY OF APPLICABLE RESEARCH EFFORTS

BRAKES

Aitken, G. J. M. Inductive Coupling for Transmission of Braking Signals in Long Freight Trains. Canadian Institute of Guided Ground Transport, Queen's University at Kingston, Ontario. CIGGT Report No. 77-4 (Transport Canada Report No. TP 848). January 1977.

Blaine, D. G., F. J. Grejda, and J. C. Kahr. Braking Duty in North American Freight Train Service and Effects on Brake Equipment, Brake Shoes and Wheels. American Society of Mechanical Engineers Paper No. 78-RT-9 for presentation at the IEEE-ASME Joint Railroad Conference, St. Paul, MN, April 11-13, 1978.

Eshelman, L. L., C. C. Shelleman, and J. P. Henderson. Brake System Design Optimization, Volume I: A Survey and Assessment. U.S. Dept. Transportation/Federal Railroad Administration Report No. FRA/ORD-78/20, I. Final Report, June 1978.

Grejda, F. J. Computer Simulation of Train Braking Performance. Paper presented at The Air Brake Association Annual Meeting, September 13, 1972.

Hart, J. E. Train Braking Analysis Through Computer Simulation. Paper presented at The Air Brake Association Annual Meeting, September 17, 1974.

Kearney Management Consultants. Brake System Design Optimization - A Survey and Assessment, Volume II: Supplemental Data. (Unpublished Report)

Low, E. M. and V. K. Garg. Technical Documentation, Train Operations Simulator. Association of American Railroads Report No. R-269. August, 1977.

Martin, G. C. and H. Tideman. Technical Documentation, Detailed Train Action Model. Association of American Railroads Report No. R-221. February 1977.

Palmer, D. E. Brake System Leakage - 1975. Paper presented at The Air Brake Association Annual Meeting, September 15, 1975.

Trevisin, R. F. Sonicar. American Society of Mechanical Engineers Paper No. 68-WA/RR-8 for presentation at the ASME Winter Annual Meeting and Energy Systems Exposition, N.Y., N.Y., December 1-5, 1968.

COUPLERS AND DRAFT GEAR

Hsu, T-K. and D. A. Peters. A Simple Model for Simulating Draft-Gear Behavior in Rail-Car Impacts. American Society of Mechanical Engineers Paper No. 78-RT-2 for presentation at the Rail Transportation Conference, St. Paul, MN, April 11-12, 1978.

Morella, N. A., S. K. Punwani, M. A. Scott, and K. L. Shum. Draft Gear/Cushioning Unit Optimization for Train Action - Interim Report. Association of American Railroads Report No. R-308 for period June 2, 1968 to May 1978.

Nyquist, A. E. et al. Coupling System Design Optimization. A Survey and Assessment of Automatic Coupling Concepts for Rail Freight Cars. Volume I: Executive Summary. U.S. Dept. Transportation/Federal Railroad Administration Report No. FRA-ORD-78-11, I. Final Report, May 1978.

-----. Volume II: Text and Appendices. U.S. Dept. Transportation/Federal Railraoad Administration Report No. FRA-ORD-78-11, II. Final Report, May 1978.

Association of American Railroads and Railway Progress Institute. Railroad Coupler Safety Research and Test Project (An RPI and AAR Cooperative Program). Norman Morella, Project Director.

Technical Report No. 2, August 1972: Summary of Visual Inspection Results-Cracked or Broken Freight Car Couplers, Knuckles and Yokes.

Technical Report No. 3, September 1972: Statistical Summary of Joint AAR-Railroad Survey of Cracked or Broken Couplers, Knuckles and Yokes in Freight Service on Five Railroads.

Technical Report No. 4, February 1973: Current Population of Couplers and Knuckles in Freight Service Including Identification of Reclaimed Couplers.

Technical Report No. 5, June 1973: Coupler and Knuckle Service Performance.

Technical Report No. 6, July 1973: Yoke Service Program.

Technical Report No. 7, August 1976: Study of "F" Couplers Cast Before March 1970.

Technical Report No. 8, August 1976: Fracture Analysis and Material Evaluation of Butts from "F" Couplers Cast Before March 1970.

ACCIDENTS

U.S. Department of Transportation/Federal Railroad Administration, Office of Safety. Accident Bulletin No. 143, Calendar Year 1974. Summary and Analysis of Accidents on Railraods in the U.S.

-----. Accident/Incident Bulletin No. 144, Calendar Year 1975.

-----. Accident/Incident Bulletin No. 145, Calendar Year 1976.

U.S. Department of Transportation/Federal Railroad Administration. FRA Guide for Preparing Accident/Incident Reports. 1977.

OPERATIONS

Greene, L. P. et al. Advanced Freight Systems Study - Phase I, Concept Formulation/Definition-Domestic. Final Report, Phase I for Period October 1976 to August 1978. Issued August 1978.

Petracek, S. J., A. E. Moon, R. L. Kiang, and M. W. Siddiqee. Railroad Classification Yard Technology. A Study and Assessment. U.S. Dept. Transportation/Federal Railroad Administration Report No. FRA/ORD-76/304. Final Report, January 1977.

FINANCIAL AND INSTITUTIONAL

Association of American Railroads/Economics and Finance Department. Yearbook of Railroad Facts - 1978 Edition.

Hill, D. and V. deSostoa. A Costing Methodology for Freight Cars: The Conceptual Design of a Cost Information System. U.S. Dept. Transportation/ Federal Railroad Administration Report No. FRA-OPPD-78-16, Volume II of II. An Interim Report, June 1978.

Hill, D., V. deSostoa, F. Dopfel, and L. M. Vass. A Costing Methodology for Freight Cars: The Test of Incurrence/Consumption Relationships. U.S. Dept. Transportation/Federal Railroad Administration Report No. FRA-OPPD-78-17, Volume I of II. An Interim Report, June 1978.

Laughlin, Malcolm O. Cost/Profit Measurement Systems for Transportation Management Decisions. Paper presented at the Transportation Research Forum, Boston, MA, October 28-30, 1976.

McCabe, Douglas M. Railroad Manpower Adjustments to Technological Change Through Collective Bargaining. Cornell University, May 1977.

Mitre Corporation/Metrek Division. Railroad Cargo Damage and Loss Statistics. Working Paper No. 13169. June 1978. (Controlled Distribution

National Academy of Sciences/Transportation Research Board. Railroad Research Study Background Papers, June 30 - July 25, 1975:

Ingraham, J. W. and John R. Whitman. A Capital Markets Approach to the Financial Needs of the Railroad Industry.

Weller, J. L. and L. H. Keely. Capital Scarcity and Transportation Planning.

Reebie Associates. National Intermodal Network Feasibility Study. Volume I-IV, Part 1. U.S. Dept. Transportation/Federal Railroad Administration Report No. FRA-OPPD-76-2, I. May 1976.

U.S. Department of Transportation. A Prospectus for Change in the Freight Railroad Industry. A Preliminary Report by the Secretary of Transportation. October 1978.

Wyckoff, D. Daryl. Railroad Management. Lexington, MA, Lexington Books, 1976.

EXAMPLE

IMPLEMENT REMOTE UNCOUPLING, REMOTE HAND BRAKE APPLICATION, AND REMOTE ANGLE COCK CONTROL

STEP #1. YARD TRAIN

Savings for Path Through Block 1.2

$T_{1.2.3}$ Set hand brakes on 5 cars

SHB[1]	.464 min	
Walk[2]	.2	
	.664	
	× 5	
		3.32 min.

$T_{1.2.3a}$ Trainman returns from setting brakes

Walk	.2	
	× 5	
		1.00 min.

$T_{1.2.4}$ Close loco angle cock

CAC	.2	.2

$T_{1.2.5}$ Pull pin

OK	.1	.1
		4.62 min

Probability for top path P_1 = .5

2.31 min average/train.

[1]Values of crew work elements are from p. 114 of Phase I½ report.

[2]Walk at 3 mph = 4.4 ft/sec = 0.2 min.car.

Savings for Path Through Blocks 1.1, 1.3

1.1

$T_{1.1.1}$	Trainman walks 1/2 mile	10	min
$T_{1.1.2}$	Close angle cock	.2	
$T_{1.1.4}$	Pull pin (OK)	.1	
$T_{1.1.7}$	Return trainman - 1/2 mile	10	min
		20.3	min.

1.3	(Same as block 1.2)	4.62	min
1.4	$T_{1.4.5}$ Open loco angle cock	.36	
1.5	(Same as block 1.2)	4.62	min
	Total	29.9	min
	$P_2 =$	0.5	
		14.95	min/average train

Assume $P_Y = 1.0$ at Decision 1b

Total Savings - Step 1

 2.31
14.95
17.26 min/train

or $\frac{17.26}{67} = 0.263$ min/car classified[1].

[1] 67 cars/train - 1978 Yearbook of Railroad Facts, p. 39.

STEP #2. CLASSIFY CARS — FLAT YARD

Dec. 2a: Cut length - assume $P_Y = 1$

Dec. 2d: Special handling - assume $P_N = 1$

Dec. 2f: Free knuckle - assume $P_N = .75$

$P_Y = .25$

2.2

$T_{2.2.1}$ Walk 5 cars (5 × .2) 1 min

$T_{2.2.2}$ RHB (.142 × 5) .71

1.71 min/cut of 67 cars

.0255 min/car

Decision 2f → Σ

Top path $P_N \times 0 = 0$

Bottom path $P_Y \times T_{2.10.1} = 0.25 \times .147 = .0368$

Total = .0368 min/car.

Block 2.11

$T_{2.11.5}$ = .097 min/car.

Total Savings — Step 2

.0255
.0368
.097

.159 min/car .

STEP #3. PULL DOWN

Block 3.2

$T_{3.2.3}$ Release HB (5 cars)

RHB	.142
Walk	.2
	.342
	× 5
	1.71 min/cut

Assume 22 cars/cut

Therefore $\frac{1.71}{22} = .0777$ min/car.

Decision 3a → Σ

$P_1 = .85$ (Mechanicsville data)

$P_2 = .10$ (Assumption)

$P_3 = .01$ (Assumption)

$P_4 = .01$ (Assumption)

$P_5 = 0$ (Mechanicsville data)

$P_6 = .01$ (Assumption)

$P_7 = .0004$ (Mechanicsville data)

$P_8 = .0196$ (Assumption) .

Assume remote uncoupler eliminates closed knuckle rebound and by-passes. Also assume

$$T_{3.6} = T_{3.8} = 2 \text{ min}$$

Then

$$T_{total} = P_4 \times T_{3.6} + P_6 \times T_{3.8}$$
$$= .01 \times 2 + .01 \times 2$$
$$= .04 \text{ min/car} .$$

Decision 3b → Σ

$$P_Y = .33$$
$$P_N = .67$$

Top path (set 5 HB)

SHB	.464	
W	.2	
	.664	
	× 5	
		3.32 min/cut
Walkback		1.00 min/cut
OK		.1
		4.42 min/cut

or $\frac{4.42 \text{ min/cut}}{22 \text{ cars/cut}} \times (P_Y = .33) = .0663$ min/ave car.

Bottom path

$$T = P_N \times OK = .67 \times .097 = .065 \text{ min/ave cut}$$

$$\text{or} \quad \frac{.065}{22} = .003 \text{ min/ave car}$$

Total = .0663 + .003 = .0693 min/car.

Decision 3c → Σ

Assume $P_Y = 1.0$

$$\text{Time} = \text{OAC} + \text{Walk} + \text{CAC} + \text{OK}$$
$$= .357 + .2 + .2 + .097$$
$$= .854 \text{ min/train}$$

$$\text{Time} = \frac{.854}{67} = .0127 \text{ min/car}$$

Block 3.15

T ≈ .357 min/car (OAC time).

Decision 3d

Assume yard air is used to charge train.

Block 3.19

$$T = \frac{\text{OAC}}{67} = \frac{.357}{67} = .005 \text{ min/car.}$$

Block 3.21

Release 5 HB (same as 2.2) = .0255 min/car.

Total — Step 3

Block 3.2	.0777 min/car
Dec 3a → Σ	.04
Dec 3b → Σ	.0693
Dec 3c → Σ	.0127
Block 3.15	.357
Block 3.19	.005
Block 3.21	.0255
	.5872 min/car.

STEP #4. POWER BRAKE TEST

No savings.

Total Savings

Step #1	0.263 min/car
Step #2	.159
Step #3	.587
Step #4	0.0
	1.009 min/car.

Labor

Since 300 mil cars are classified annually[1]

$$\text{Labor savings} = 3\ \frac{\text{men}}{\text{crew}} \times 1.0\ \frac{\text{min}}{\text{car}} \times 300 \times 10^6\ \frac{\text{cars}}{\text{yr}}$$

$$\times \frac{1}{120{,}000}\ \text{min/man year}$$

$$= 7500\ \text{man years/yr}$$

$$\text{or } 7500\ \text{man years} \times 22{,}000\ \frac{\text{dollars}^2}{\text{man year}} = \$165\ \text{million/year of labor costs.}$$

[1]Petracek, *et al.*, "Railroad Classification Yard Technology," FRA/ORD-76/304.

[2]1978 Yearbook of Railroad Facts, p. 58.

PRELIMINARY

YARD OPERATIONAL INFORMATION QUESTIONNAIRE

BACKGROUND

Railroad:____

Name of Person Answering Questionnaire:________________________

Yard Name:____

Yard Type (check one)

Classification - Flat ☐

Classification - Hump ☐

Industrial ☐

Average daily number of inbound trains:________________________

Average daily number of outbound trains:________________________

Average daily number of cars handled:________________________

OPERATIONAL QUESTIONS

1. For inbound trains, what percentage are yarded:
   - directly?________
   - in two blocks?________
   - in more than two blocks?________
2. What percentage of cabooses of inbound trains remain with cars when train is yarded?________________________
3. When a cut of cars is moved to a switch or hump lead, what percentage of the time does it have to be uncoupled from remaining cars?____________
4. What percentage of cars require special handling during classification?

   ____

5. For what percentage of cars will a trainman cross over and open knuckle during kicking or humping operations?____________________

Flat Switching Only

6. On the average, how many cars are kicked before the switch engine backs the cut to resume switching?____________________

7. What percentage of humped or kicked cars require a brakeman to ride on the car and set the handbrake?____________________

8. What percentage of humped or kicked cars are found in the following condition on classification tracks?

   Coupled?____________________

   Stopped Short?________________

   Rebound (open knuckle)?__________

   Rebound (closed knuckle)?________

   Coupler bypass (hi-lo)?__________

   Coupler bypass (side)?___________

   Broken coupler?_______________

   Miscoupled for other reasons?_____

9. On the average, how many blocks make up an outbound train?____________

10. What percentage of outbound trains have cabooses?____________________

11. Are brakes changed by (check one):

   road locomotives ☐

   yard air ☐

   switch engines ☐

12. What percentage of power brake tests fail because

   a. brake pipe pressure at rear of train is not greater than 60 psi and within 15 psi of feed valve pressure?____________________

   b. The leakage rate is greater than 5 lb/min?____________________

c. One or more cars fails brake application/release inspection?________

d. Other reasons related to the brake system?__________________________

AVERAGE YEARLY MAXIMUM POTENTIAL BRAKING AND COUPLING COST SAVINGS

Average Equipment and Track Damage	53,642,000
Average Lost Wages (Accident)	187,000
Average Lost Wages (Incident)	898,000
Average Lading Damage	16,000,000
Average Total Accident Cost	70,727,000
Average Fatalities	11

OBJECTIVES OF FINANCIAL MODEL

- Estimates Amount Available For Fleet Conversion
- Estimates Value of System to Individual Railroads

SPECIFICATIONS

Net Present Value (NPV) Model

Discounts Stream of Cash Flows:

$$NPV = \sum_{t=0}^{n} \frac{C_t}{(1+K)^t}$$

Where

C_t = After-Tax Cash Flow Generated By Project at Time t

K = Discount Rate, or "Cost of Capital"

CASH FLOW PARAMETERS

- Savings From Advanced System
  - Reduced Transportation Labor
  - More Efficient Car Utilization
  - Reduced Equipment & Lading Damage
- Cost of Car Retro Fit
- Incremental System Cost on New Cars
- Investment Tax Credits
- Tax Shields on Depreciation

MODEL VARIABLES

- Years Cash Flows to be Calculated
- Years to System Compatability
- Number of Cars in System
- Fraction of Cars Replaced Per Year
- Fraction of Retrofit Cost Per New Car Production
- Labor Savings Per Year Subject to Union Pay Out
- Number of Years of Union Pay Out
- Fraction of Labor Savings Paid to Union

MODEL VARIABLES (Continued)

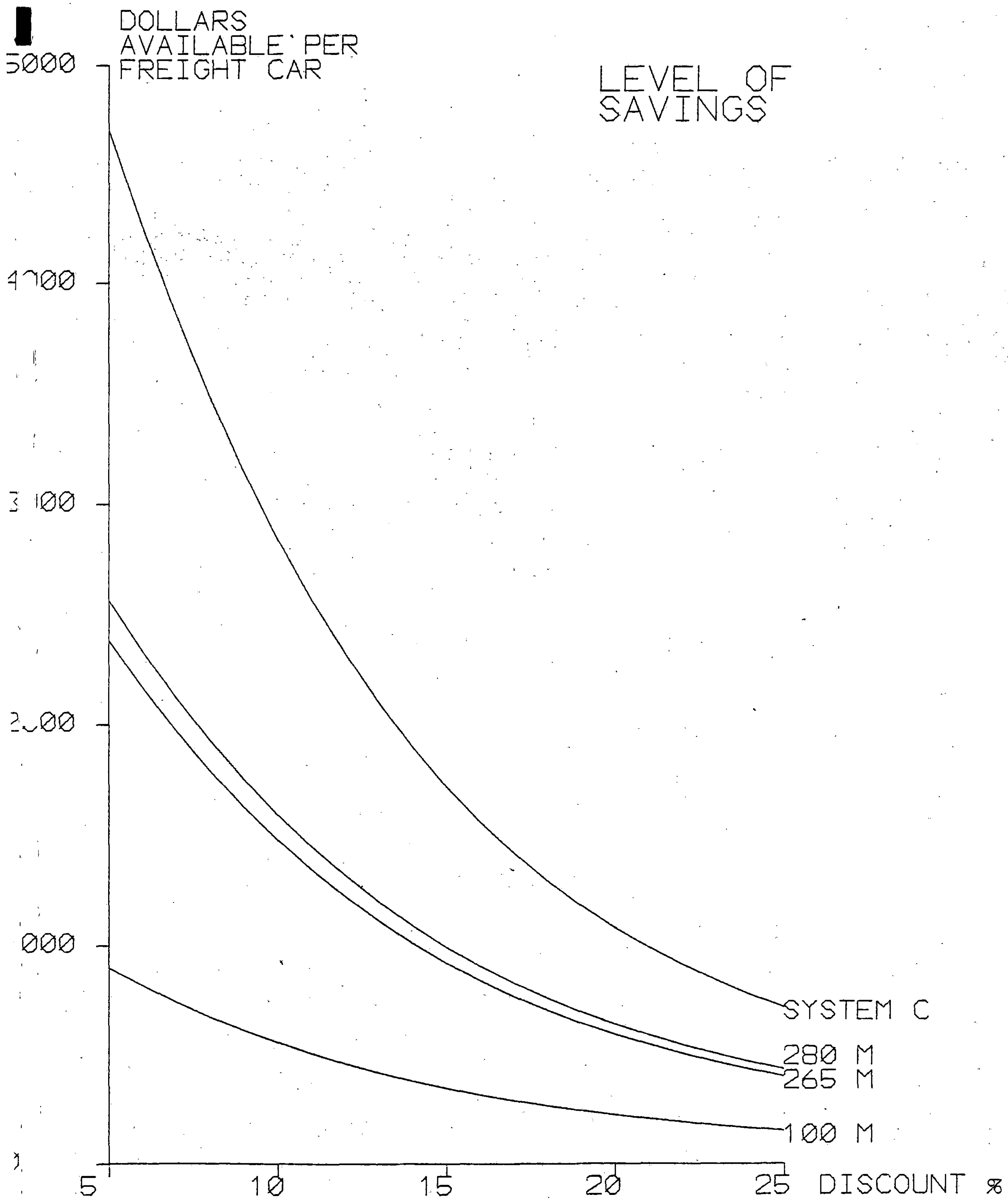
- Savings Not Subject to Union Pay Out
- Federal Tax Rate
- Fraction of Investments Deductable for ITC
- Materials / Labor Inflation Rates
- Asset Life Time
- Depreciation Method
  - Straight Line
  - Double Declining Balance
  - Sum Years Digits

EXAMPLE OF QUESTIONS ASKED BY MODEL

```
THIS IS A MODEL TO ESTIMATE THE AMOUNT THAT CAN
BE SPENT PER FREIGHT CAR FOR ADVANCED BRAKING
AND COUPLING.
FOR HOW MANY YEARS SHOULD THE CASH FLOWS BE CALCULATED?25
HOW MANY YEARS DOES THE SYSTEM TAKE TO BECOME COMPATIBLE?5
HOW MANY CARS ARE IN THE SYSTEM?1700000
WHAT FRACTION OF THE CARS HAVE TO BE REPLACED EACH YEAR?.037
WHAT FRACTION OF RETROFIT COST IS REQUIRED FOR
NEW PRODUCTION (PER CAR)?.5
FRACTION=  50.0%
IS THIS CORRECT?YES
WHAT IS THE LABOR SAVINGS PER YEAR THAT IS
SUBJECT TO UNION PAYOUT?265000000
FOR HOW MANY YEARS WILL SAVINGS BE PAID TO THE UNION?10
WHAT FRACTION OF LABOR SAVINGS ARE PAID TO THE UNION?.25
WHAT IS THE ANNUAL SAVINGS NOT SUBJECT TO
UNION PAYOUT?15000000
WHAT IS THE TAX RATE FOR THE RAILROAD INDUSTRY?.46
WHAT FRACTION OF INVESTMENTS ARE DEDUCTIBLE FOR
INVESTMENT TAX CREDIT?.1
WHAT IS THE INFLATION RATE FOR:
MATERIALS (IN PERCENT)?10
LABOR (IN PERCENT)?8.7
SAVINGS NOT SUBJECT TO UNION PAYOUT (IN PERCENT)?10
WHAT IS THE LIFETIME OF THE ASSET?16
WHICH METHOD OF DEPRECIATION DO YOU WANT TO USE?
         STRAIGHT     -STRAIGHT LINE
         DOUBLE       -DOUBLE DECLINING BALANCE
         SUM          -SUM OF YEARS DIGITS
```

ASSUMPTIONS FOR 265M CURVE

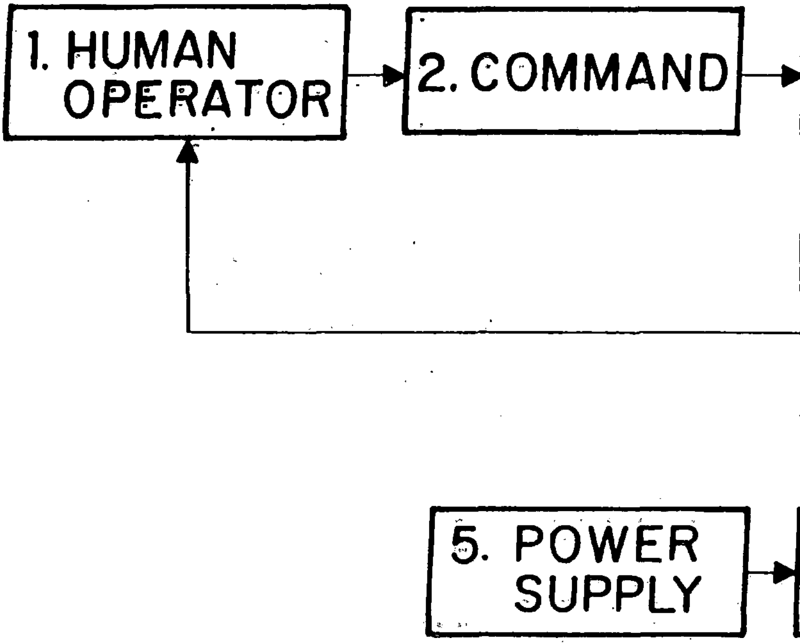
VARIABLE	KEYWORD	CURRENT VALUE
NUMBER OF YEARS IN ANALYSIS	LIMIT	25
YEARS BEFORE SYSTEM IS COMPATIBLE	COMPATIBLE	5
NUMBER OF CARS	NUMBER	1700000.000
ATTRITION RATE	ATTRITION	0.037
NEW COST OF EQUIPMENT	FRACTION	0.500
INVESTMENT TAX CREDIT	INVESTMENT	0.100
TAX RATE	TAX	0.460
LOSS TO UNION	UNION	0.250
LABOR SAVINGS	SAVINGS	265000000.000
YEARS SAVINGS ARE LOST TO UNION	LOSE	10
OTHER SAVINGS	OTHER	15000000.000
INFLATION:	INFLATION	
MATERIALS		1.100
LABOR		1.087
OTHER		1.100
MINIMUM DISCOUNT RATE	RATES	5
MAXIMUM DISCOUNT RATE	RATES	25
DEPRECIATION	DEPRECIATION	
LIFETIME OF ASSETS		16
SUM OF YEARS DIGITS DEPRECIATION USED.		


DOLLARS
AVAILABLE PER
FREIGHT CAR
LEVEL OF
SAVINGS
5000
000
SYSTEM C
280 M
265 M
100 M
5
10
15
20
25
DISCOUNT %

PRELIMINARY IDENTIFICATION OF EXISTING COMPONENTS

	BASELINE	ALTERNATIVE
Coupler	Type E	1. Type F 2. Type E with Shelves
Brake Valve	ABDW	———
Brake Cylinder	Car-Mounted	Truck Mounted
Brake Shoes	Cast Iron	1. High-Phos 2. Composition

BLOCK DIAGRAM OF



TRAIN CONTROL SUBSYSTEMS

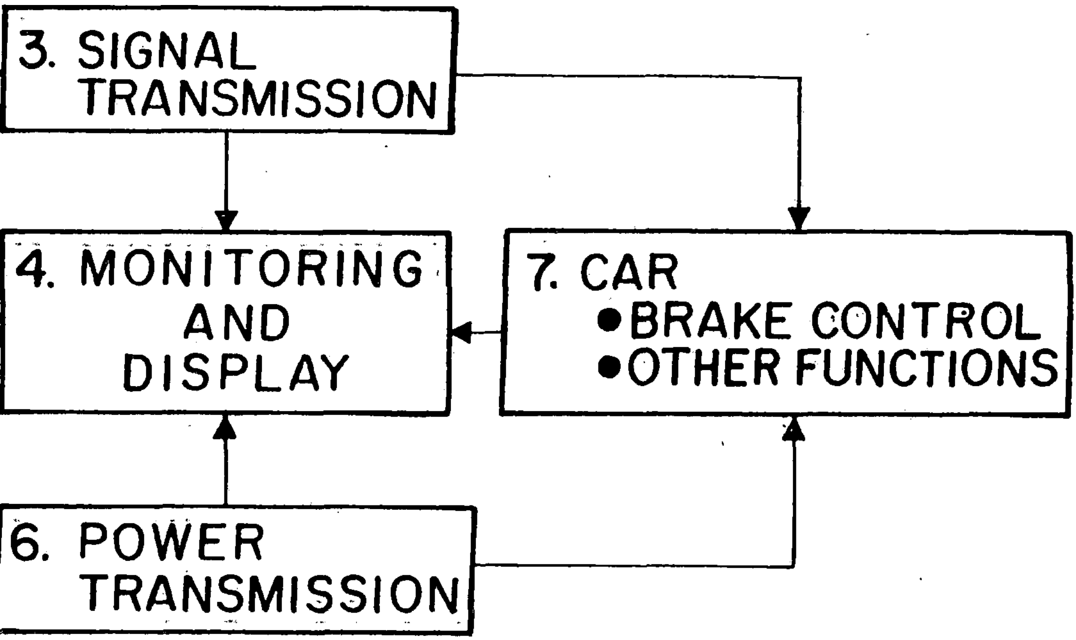


TABLE 2.8 BRAKING AND COUPLING SUBSYSTEMS FOR CONVENTIONAL FREIGHT SYSTEMS AND FOR AN ATCS.

Subsystems		Freight System	Candidate Components and Subsystems For An Advanced Train Control System
1. Human Operator(s)		Engineman Brakeman Conductor	(Same)
2. Command	Automatic brakes	Automatic brake valve	1. Valve system
	Independent brakes	Independent brake valve	2. Two-lever force/slack system with mini-computer
	Dynamic brakes	Braking lever	
3. Signal Transmission		Brake pipe	1. Electrical wires 2. Radio link
4. Monitoring and Display	Automatic brakes	Air gauge — brake pipe at locomotive	1. Gauges and meters
	Independent brakes	Air gauge — locomotive brake cylinder	2. Digital readout of car condition variables
	Dynamic brakes	Brake current indicating meter	
	Drawbar pull	Load indicating meter	
	Speed	Speedometer	
5. Power Source	Pneumatic	Air compressor and main reservoir	(Same)
	Electrical	-	1. Locomotive generator 2. Car-mounted alternator
6. Power Transmission	Pneumatic	Brake pipe	(Same)
	Electrical		Electrical wires
7. Car Brake Control	Energy storage	Auxiliary and emergency reservoirs	1. Reservoirs 2. Battery
	Controller	Control valve	1. Electronic control unit 2. Servo valve
	Force actuator	Brake cylinder	1. Pneumatic/mechanical brake cylinder 2. Pneumatic/hydraulic brake cylinder
	Force transmission	Foundation brake rigging	1. Linkages 2. Hydraulic brake line
	Force application	Shoes/wheel	(Same)
8. Other Command, Monitoring and Display			1. Coupler command and monitoring 2. Coupler position monitoring 3. Car condition monitoring - wheel slip - bearing vibration - refrigeration temperature - tank pressure

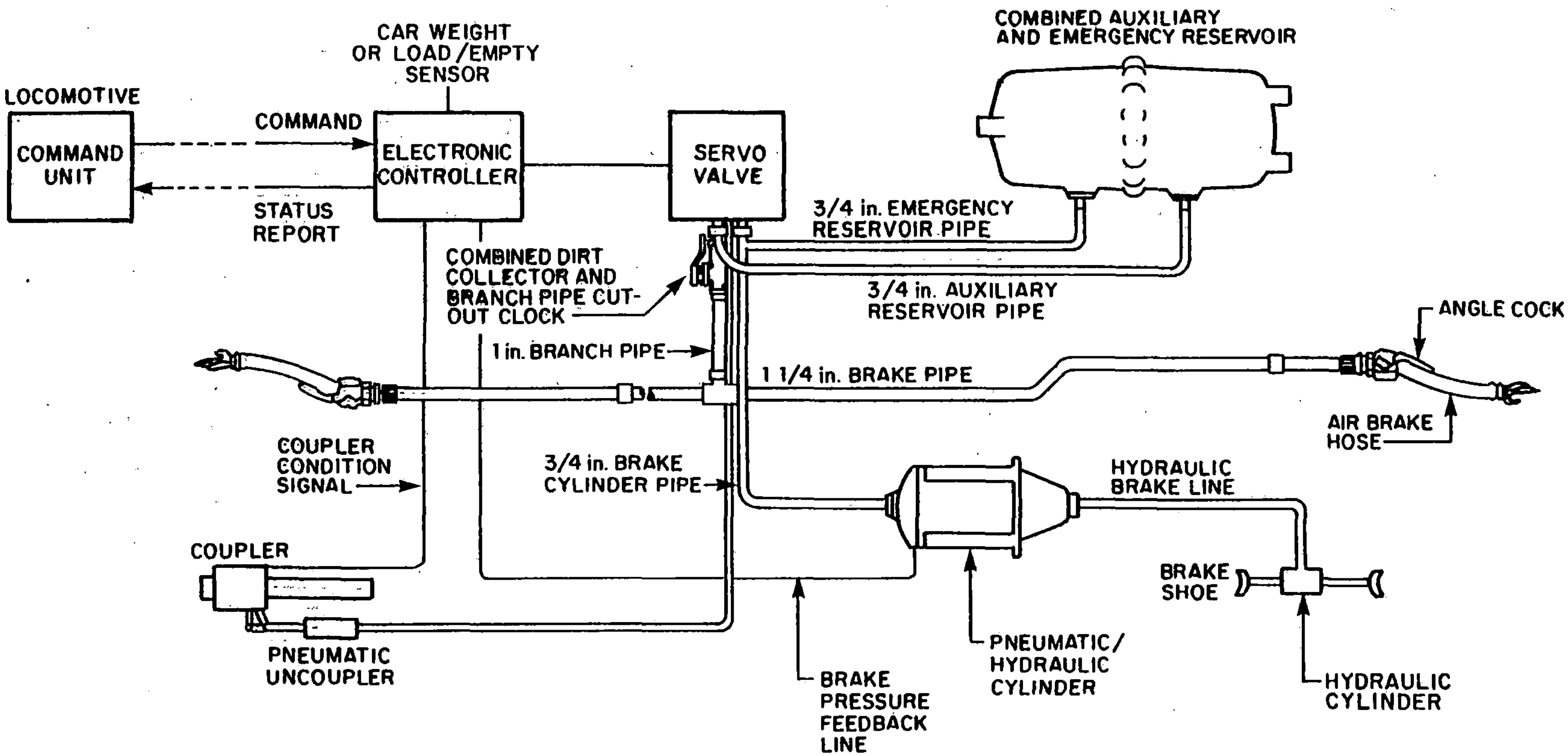


FIG. 2.19. CANDIDATE ELECTRO/PNEUMATIC/HYDRAULIC FREIGHT CAR CONTROL SYSTEM.

[redacted]

PRELIMINARY IDENTIFICATION OF INNOVATIVE COMPONENTS AND CONCEPTS

	1. Increase Gathering Range
1. Knuckle Open	2. Eliminate Trainman Crossover
2. Coupler Centering and Positioning Devices	• Less Coupler Bypass
3. Automatic Airline Connection	• Eliminate Manual Hose Coupling
4. Load Empty and Load Proportional Devices	• Faster Stopping • Lower Buff and Draft Forces
5. Non-compatible Coupler (Willison, Horn & Funnel)	• Gathering Range • Electrical Connection
6. Locomotive-controlled Coupler	• Eliminate Pin Puller
7. Locomotive-controlled Angle Cock	• Labor
8. Electronically Controlled Brakes	• Faster Stopping • Remote Hand Brakes • Automatic Bleed
9. Train Condition Sensors	• Reduce Accidents

5. PICK UP AND DELIVERY

4. POWER BRAKE TEST

3. PULL DOWN


UNIT CONSIDERED
CUT →
CAR →
CUT →
TRAIN →
2
3.1
C T
1. MOVE SWITCH ENGINE TO CLASS TRACK
$T_{3.1.1}$
3.2
C T
1. SIGNAL STOP
2. COUPLE ENGINE TO LEAD CAR
3. RELEASE HANDBRAKES
$T_{3.2.1}$
$T_{3.2.2}$
$T_{3.2.3}$
3a
COUPLER CONDITION ?
P_1
P_2
P_3
P_4
P_5
P_6
P_7
P_8
3.3
1. COUPLED
3.4
2. U.C. (STOPPED SHORT) COUPLE
3.5
3. U.C. (REBOUND OPEN-K) COUPLE
3.6
4. U.C (REBOUND CLOSED-K) COUPLE
3.7
5. U.C. (BYPASS - HI/LO) COUPLE
3.8
6. U.C. (BYPASS - SIDE) COUPLE
3.9
7. U.C. (BROKEN COUPLER) COUPLE
3.10
8. U.C. (OTHER) COUPLE
Σ
3.11
C T
1. MOVE BLOCK TO DEPARTURE TRACK
3b
IS THIS 1ST BLOCK OF CARS?
P_Y
P_N
3.12
C T
1. SET HANDBRAKES
2. PULL PIN
3. SIGNAL START
4. UNCOUPLE CARS
SHB
OK
$T_{3.12.1}$
$T_{3.12.2}$
$T_{3.12.3}$
$T_{3.12.4}$
3.13
1. SIGNAL STOP
2. COUPLE TO WAITING BLOCK
3. PULL PIN
4. SIGNAL START
5. UNCOUPLE CARS
OK
$T_{3.13.1}$
$T_{3.13.2}$
$T_{3.13.3}$
$T_{3.13.4}$
$T_{3.13.5}$
Σ
3c
DOES TRAIN NEED A CABOOSE?
P_Y
P_N
3.14
C T
1. MOVE CABOOSE TO END OF TRAIN
2. SIGNAL STOP
3. COUPLE CABOOSE TO CARS
4. CONNECT AIR LINES AND
5 OPEN ANGLE COCKS
6 CLOSE ANGLE COCKS BETWEEN CABOOSE + LOCO
7. PULL PIN
8. SIGNAL START
9. UNCOUPLE LOCO
OAC
CAC
OK
$T_{3.14.1}$
$T_{3.14.2}$
$T_{3.14.3}$
$T_{3.14.4}$
$T_{3.14.5}$
$T_{3.14.6}$
$T_{3.14.7}$
$T_{3.14.8}$
$T_{3.14.9}$
3.15
C T
1. SET BLUE FLAGS
2. LACE AIR HOSES
3. OPEN ANGLE COCKS
4. CLOSE END ANGLE COCK
CH
OAC
CAC
$T_{3.15.1}$
$T_{3.15.2}$
$T_{3.15.3}$
$T_{3.15.4}$
3d
METHOD TO CHARGE TRAIN
P
P
P
3.16
C T
1. MOVE ROAD LOCO(S) TO HEAD OF TRAIN
2. SIGNAL STOP
3. COUPLE ROAD LOCO(S)
4 OPEN ANGLE COCKS
5 CHARGE BRAKES
3.17
C T
1. CONNECT YARD AIR
2. CHARGE BRAKES
3. DISCONNECT YARD AIR
3.18
C T
1. BRING IN YARD ENGINE TO CHARGE TRAIN
2. CONNECT AIR LINE
3. OPEN LOCO ANGLE COCK
4. CHARGE BRAKES
5. CLOSE ANGLE COCKS BETWEEN LOCO + 1st CAR
6. REMOVE LOCO
3.19
C T
1. MOVE ROAD LOCO(S) TO HEAD OF TRAIN
2. SIGNAL STOP
3. COUPLE ROAD LOCO(S)
4. OPEN ANGLE COCKS
5 CHARGE BRAKES
OAC
3.20
C T
1. MOVE ROAD LOCO(S) TO HEAD OF TRAIN
2. SIGNAL STOP
3. COUPLE ROAD LOCO(S)
4. OPEN ANGLE COCKS
5. CHARGE BRAKES
Σ
3.21
1. RELEASE HANDBRAKES
3

2 CLASSIFICATION


UNIT CONSIDERED
TRAIN →
TRAIN ARRIVES
1a
1 HOW MANY BLOCKS ARE REQUIRED ?
2
P1
P2
1.1
C T
1. POSITION TRAINMAN AT CUT | W | | T1.1.1
2 CLOSE ANGLE COCK AT CUT | CAC | | T1.1.2
3 RELEASE AIR BRAKES | | | T1.1.3
4 PULL PIN | OK | | T1.1.4
5 SIGNAL START | | | T1.1.5
6. UNCOUPLE CARS | | | T1.1.6
7. RETURN TRAINMAN TO LOCO (2 man cr. only) | | | T1.1.7
1.2
C T
1. MOVE CUT TO RECIEVING TRACK | | | T1.2.1
2 SERVICE APPLICATION | | | T1.2.2
3 SET HANDBRAKES ON 1ST FEW CARS | SHB | | T1.2.3
4 CLOSE LOCO ANGLE COCK | CAC | | T1.2.4
5. PULL PIN | OK | | T1.2.5
6. SIGNAL START | | | T1.2.6
7. UNCOUPLE LOCOMOTIVES | | | T1.2.7
1.3
C T
1. MOVE CUT TO RECIEVING TRACK | | | T1.3.1
2. SERVICE APPLICATION | | | T1.3.2
3. SET HANDBRAKES ON 1st FEW CARS | SHB | | T1.3.3
4. CLOSE LOCO ANGLE COCK | CAC | | T1.3.4
5. PULL PIN | OK | | T1.3.5
6. SIGNAL START | | | T1.3.6
7. UNCOUPLE LOCOMOTIVES | | | T1.3.7
1.4
C T
1. RETURN LOCO(S) TO WAITING CARS | | | T1.4.1
2 SIGNAL STOP | | | T1.4.2
3 COUPLE TO HEAD CAR | | | T1.4.3
4 CONNECT AIR LINE | CH | | T1.4.4
5. OPEN LOCO ANGLE COCK | OAC | | T1.4.5
6. CHARGE BRAKES | A | | T1.4.6
1.5
C T
1. MOVE CUT TO RECIEVING TRACK | | | T1.5.1
2. SERVICE APPLICATION | | | T1.5.2
3. SET HANDBRAKES ON 1ST FEW CARS | SHB | | T1.5.3
4. CLOSE LOCO ANGLE COCK | CAC | | T1.5.4
5. PULL PIN | OK | | T1.5.5
6. SIGNAL START | | | T1.5.6
7. UNCOUPLE LOCOMOTIVES | | | T1.5.7
Σ
1b
DOES CABOOSE REMAIN WITH CARS?
PY
PN
C T
1. MOVE LOCO(S) TO CABOOSE
2. SIGNAL STOP
3 COUPLE LOCO(S) TO CABOOSE
4. BLEED CABOOSE BRAKES | BC
5 PULL PIN
6. SIGNAL START
7. UNCOUPLE CABOOSE
8. REMOVE CABOOSE
Σ
C T
1. BLUE FLAG TRACK
2 WALK + INSPECT | WI
3 BAD ORDER AS NECC. | BOC
4. BLEED BRAKES | BC
1

1. YARD TRAIN

Program Review, Braking and Coupling Systems Design Optimization, 1979
Bolt Beranek and Newman, Inc.