DESIGN TECHNIQUES OF FEEDER-DISTRIBUTION CABLE ENGINEERING (SAVE)

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1. GENERAL

1.1 This section provides REA borrowers, consulting engineers and other interested parties with techniques for using the Serving Area Value Engineering (SAVE) concept in the design of rural telephone plant.

1.2 This design method has two basic purposes.

1.2.1 To provide a systematic and consistent approach to the use of electronics on an economical basis. It provides for a circuit pricing technique to compare costs on each route for the different types of facilities, i.e. physical or carrier derived circuits. This technique is based on comparing the circuit costs on an annual charge basis.

1.2.2 To provide for interface equipment which separates the distribution pairs (used by installers and operating personnel) from the feeder pairs (used by cable splicing personnel).

1.3 The basic theoretical building block of the design method is a load coil bounded design area (DA).

1.3.1 The five-year estimates of the subscribers within these areas become the basis for the design. One or more such areas become a five-year serving area (SA).

1.3.2 Subscribers within the resulting serving area are connected to distribution cable pairs which are interconnected to feeder pairs or circuits at a control point called the Serving Area Interface (SAI). Serving area interfaces may be located at load coil locations, load section midpoints (for carrier, concentrators, and RST), major cable route branchings or other practical locations.

1.3.3 This TE&CM has been written for D-66 loading sections in the DA, but the design concepts can be used for H-88 loaded plant. See TE&CM Section 232 for the limitations for H-88 loading.

1.4 Procedures.

1.4.1 This design procedure is used for cable sizing and determining the economical application of electronic equipment.

1.4.2 The distribution pairs available to the installer personnel generally should have no load coils beyond the interface. The feeder circuits toward the office will have load coils, electronic equipment, or whatever is needed to provide proper transmission from this point. These feeder circuits are either physical pairs or pair gain (carrier, concentrator, lightwave, or remote switching terminal (RST)) derived pairs.

1.4.3 This practice is written so that the process and procedures can be followed and a design completed on a manual basis. It is organized such that large amounts of data are processed repetitively and cumulatively. Therefore, it is adaptable to computer-aided processing. A computerized SAVE process should be used in most cases.

2. SERVING AREA DESIGN CONSIDERATIONS

2.1 The Serving Area Interface (SAI).

2.1.1 Location of the SAI.

2.1.1.1 The first SAI is the central office (CO) mainframe. SAI's located in the field should be located where there is a logical need. This could be at major road junctions, at cable branching points, at load points, or any other practical location.

2.1.1.2 When carrier or concentrator systems are involved, it may be necessary to place interfaces at load section midpoints. The end section limitations from the load points must be observed as discussed in TE&CM Sections 232 and 424.

2.1.2 Cable considerations at the SAI.

2.1.2.1 Physical circuits 18 kft or more from the central office or an RST will require loaded cable pairs. If the DA starts at a load point, the serving area (SA) can generally extend two load sections without loading of distribution pairs as long as the combined transmission loss of the feeder and distribution pair does not exceed 8 dB at 1000 Hz. If the transmission loss limit is exceeded, the loading system may need to extend into the distribution pairs.

2.1.2.2 Where two cable routes come into an interface, the worksheets should show a DA block for each. Each block is used for the cables on that route. The CUM (Cumulative) block will include both routes. A DA block is a means of recording the circuit requirements at the SAI.

2.1.3 Equipment considerations at the SAI.

2.1.3.1 In applying grouped station carrier at an SAI, the length of the distribution pair is limited to the ohms loop limit of the carrier

equipment beyond the subscriber terminal (450 to 1000 ohms). With 24 gauge plant this may be exceeded in one load section.

2.1.3.2 In applying distributed station carrier, the subscriber terminal can be placed close to the subscriber.

2.1.3.3 From a digital subscriber carrier or line concentrator terminal, loading of the distribution pairs is not needed if the subscriber loop is less than 18 kft. For distribution pairs longer than three load sections it may be necessary to place the terminal at the load section midpoint to insure adequate voice frequency transmission. If voice frequency repeaters are required on the field side, the subscriber terminal should be placed midpoint between two load coils. Refer to TE&CM 232 and 424. The longest distribution pairs should be limited to six D-66 load points. SAI's are recommended for control purposes on the longer loaded extensions off of the carrier terminal. It is advantageous to group digital systems as much as possible since ac power must be provided at the subscriber carrier location. When three or more digital systems are required at a location, consider the use of a subscriber line concentrator (SLC) with integral digital carrier (IDC).

2.2 Development of Typical Outside Plant Cost Information.

2.2.1 Using this design method, it has been found that reinforcing cables are generally a uniform size between load coils. Typical cost data has been presented and conveniently summarized in that form in Table 1.

2.2.2 The installed cost per D-66 section can be represented approximately by the linear equation $y = m x + b$. The base cost "b" is equal to the total labor and material cost per D-66 section, independent of the number of pairs. The incremental cost per pair (section) "m" is equal to the placing and splicing cost per pair section. The number of cable pairs is equal to "x". The base cost "b" and the incremental cost per D-66 section "m" can be found graphically or by using linear regression analysis which can be performed using a programmable calculator. In Figure 1 the points represent the typical national average installed cost per 24 gauge D-66 section. The dashed line represented the result of a linear regression analysis program. The average incremental cost is $67 per pair section and the base cost is $1,684 per section.

2.2.3 For new cable construction or applications where the existing cables are unsuitable for pair gain equipment (i.e. water filled buried air core cable), the base cost would be common to both the physical and pair gain designs, and the base cost is not necessarily included in a cost comparison. The base cost would be necessary to obtain an estimate of the total project cost.

UNIT	INSTALLED* COST PER D-66 SECTION		
	LOW 85% of AVG.	AVERAGE	HIGH 115% of AVG.
BFC 6-24	$ 1,850	$ 2,177	$ 2,504
BFC 6-22	2,068	2,433	2,798
BFC 12-24	2,162	2,544	2,926
BFC 12-22	2,474	2,910	3,347
BFC 18-24	2,526	2,972	3,418
BFC 18-22	2,951	3,472	3,993
BFC 25-24	2,998	3,527	4,056
BFC 25-22	3,344	3,934	4,524
BFC 50-24	4,378	5,151	5,924
BFC 75-24	5,844	6,875	7,906
BFC 100-24	7,055	8,300	9,545
BFC 150-24	9,605	11,300	12,995
BFC 200-24	12,495	14,700	16,905
BFC 300-24	18,275	21,500	24,725
BFC 400-24	24,225	28,500	32,775
BFC 600-24	35,700	42,000	48,300
		TREND LINE COSTS Base Cost per Section	
24 gauge	$1,431	$1,684	$1,937
22 gauge	1,670	1,964	2,259
		INCREMENTAL COSTS Per Pair - Section	
24 gauge	$57	$67	$79
22 gauge	$68	$89	$92

	INSTALLED COST PER UNIT
BD-3	$ 60
BD-4	70
BD-5	90
BDS-100	300
BDS-200	450
BDS-300	700
Electronic Housing -5'	600
Electronic Housing -7'	750

* Assumes 4.5 kft cable per section and includes splicing and appropriate BM units. These costs are presented for suggested format only. Develop costs considering local conditions. See paragraph 2.2.2.

TABLE 1
TYPICAL OUTSIDE PLANT NATIONAL COST DATA

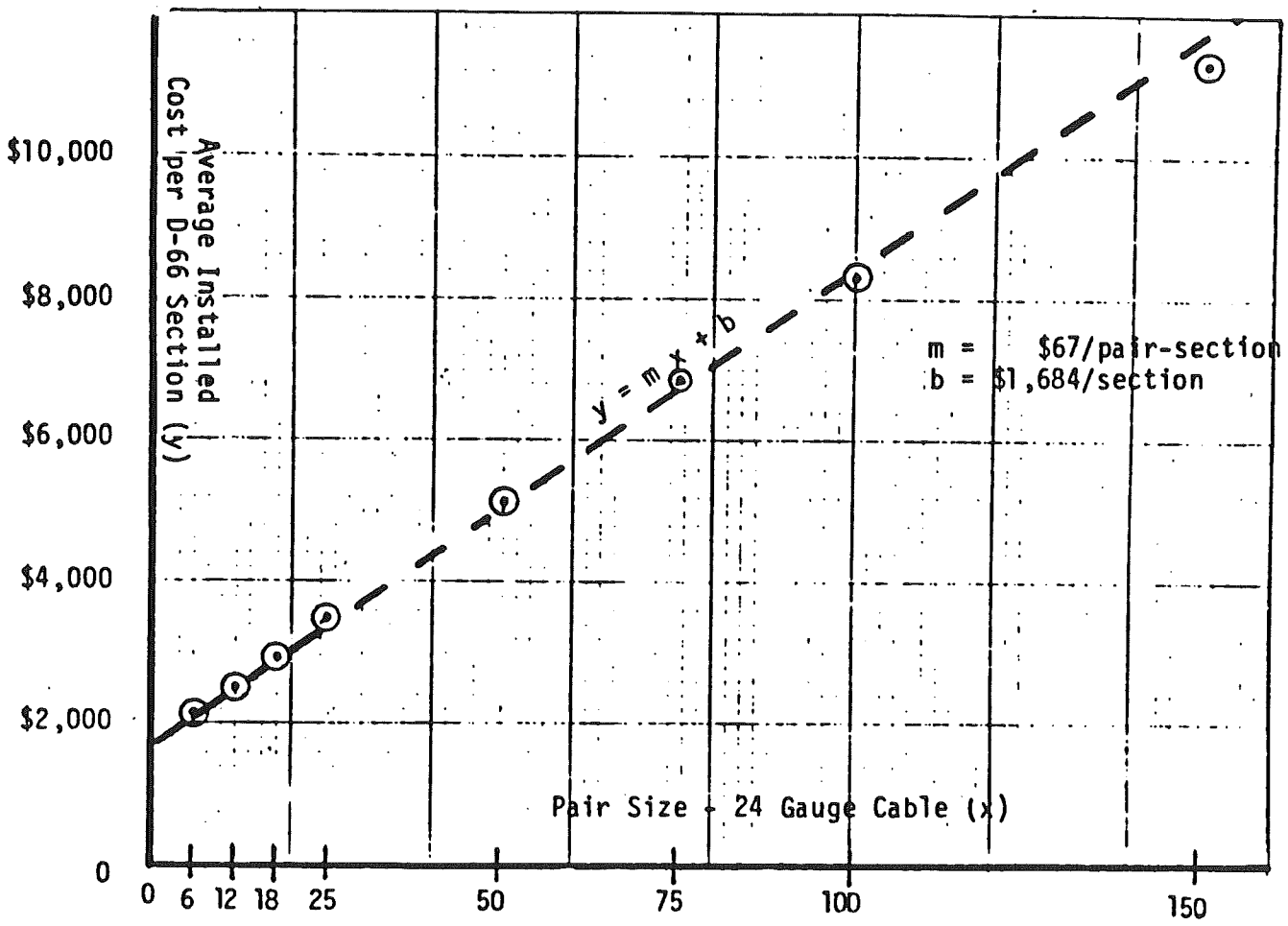


FIGURE 1
TYPICAL NATIONAL AVERAGE CABLE COSTS

2.2.4 Both the incremental and base cost apply to designs in which the existing cable is suitable for pair gain equipment. Once the appropriate cable size has been determined, either the individual cable costs or the equation ($y = m x - b$) can be used in preparing the physical versus pair gain cost comparison.

2.2.5 Since in many instances an adequate number of distribution housings are in place, new ones are priced separately rather than averaged.

2.2.6 Most load coils being added will be in 25-pair splice multiples.

2.2.7 See TE&CM Section 629, Cable Plant Layout, and TE&CM Section 648, Serving Area Value Engineering - (Physical Plant), for a more detailed outside plant discussion.

2.3 Developing Typical Electronic Cost Information.

2.3.1 The adjusted carrier cost in Tables 2, 3, and 4 is based on the fact that where carrier may prove economical the alternative voice frequency feeder circuits will require electronic equipment.

2.3.2 In Tables 2, 3, 4, and 5 it is assumed that load coils, loop extenders and voice frequency repeaters normally will have the same annual costs as carrier (or RST's). On feeder circuits where loaded pairs compete with carrier, it is expected that the cable pairs on which load coils are initially installed will gradually be converted to carrier circuits. Load coils are therefore given the same annual cost percentage as electronic equipment in the adjusted annual cost tables.

2.3.3 In Tables 2, 3, 4, and 5 the cost of one circuit of voice frequency "electronic" equipment required for physical feeders is subtracted from the cost of various types of carrier channels or RST lines to obtain a net incremental cost for comparison.

2.3.4 The difference in circuit costs developed in paragraph 2.3.3 can be compared to the cost of a physical feeder pair if the difference in annual charges between cable and electronic is recognized. The electronic annual charge (21 percent assumed) is divided by the cable annual charge (16.8 percent assumed) and the result (1.25) multiplied by the carrier differential cost developed in paragraph 2.3.3 (See Appendix 2). The results are shown in columns (h), (i), and (j) of Tables 2, 3, 4, and i, j, k, l of Table 5.

2.3.5 Care should be exercised in applying the adjusted pair gain costs for SAI's at load points 6 and 7. These costs do not include a credit for combination LE/VFR's even though the serving areas may be up to two D-66 load sections in length (9 kft) and on some loops' active loop treatment (LE/VFR) will be required. LE/VFR's are required on 24 gauge loaded loops that are over 32 kft in length which equates to L. P. 7.6. Therefore, 'break-even points' between load points 6 and 8 should be investi- gated and if necessary the credit for LE/VFR's should be included and the break-even points recomputed.

2.4 Developing Cost Comparisons

2.4.1 Typical costs (as of the issue date of this practice) for cables and pair gain feeders are used in examples in this section and are listed in Tables 1 through 5. It is recommended that Section 232 be consulted for guidelines on how to develop pair gain costs using current information for the design under consideration. Up-to-date cable and pair gain cost tables should be developed whenever the cable or equipment costs vary considerably from that used in this practice. The tables include three ranges of prices for cables but the middle range was used in the examples.

D-66 LOAD COIL LOCATIONS	STATION CARRIER FEEDER COST* PER CHANNEL		VOICE FREQUENCY LINE TREATMENT COST PER CIRCUIT			STATION CARRIER ANNUAL COST ADJUSTMENT** PER CIRCUIT	
	GROUPED STATION	DISTRIBUTED STATION	LOAD COILS	LE/VFR	TOTAL	GROUPED STATION CARRIER ADJUSTED COST	DISTRIBUTED STATION CARRIER ADJUSTED COST
	2 Sys	1 Sys				2 Sys	1 Sys
(a)	(b)	(c)	(d)	(e)	(f=d+e)	h=1.25(b-f)	i=1.25(c-f)
1	353	450	0	0	0	441	563
2	353	450	0	0	0	441	563
3	353	450	15	0	15	423	544
4	353	450	20	0	20	416	538
5	393	490	25	0	25	460	581
6	393	490	30	0	30	454	575
7	393	490	35	0	35	448	569
8	433	530	40	150	190	304	425
9	433	530	45	150	195	298	419
10	433	530	50	150	200	291	413
11	433	530	55	150	205	285	406
12	473	570	60	150	210	329	450
13	473	570	65	150	215	323	444
14	607	811	70	150	220	484	739
15	647	851	75	150	225	528	783
					Pair Gain Ratio:	8 to 1	8 to 1

TABLE 2
TYPICAL STATION CARRIER ADJUSTED ANNUAL COST

D-66 LOAD COIL LOC.	PCM (24 CH./TERMINAL) SUBSCRIBER CARRIER FEEDER COST* PER CHANNEL			VOICE FREQUENCY LINE TREATMENT COST PER CIRCUIT			PCM SUBSCRIBER CARRIER ANNUAL COST ADJUSTMENT** PER CIRCUIT		
	1 Ter	2 Ter	4 Ter	LOAD COILS	LE/VFR	TOTAL	1 Ter	2 Ter	4 Ter
(a)	(b)	(c)	(d)	(e)	(f)	(g=e+f)	h=1.25(b-g)	i=1.25(c-g)	j=1.25(d-g)
1	516	516	516	0	0	0	645	645	645
2	544	532	526	0	0	0	680	665	658
3	572	548	536	15	0	15	696	666	651
4	600	564	546	20	0	20	725	680	658
5	628	580	556	25	0	25	754	694	664
6	656	596	566	30	0	30	783	708	670
7	684	612	576	35	0	35	811	721	676
8	712	628	586	40	150	190	653	548	495
9	740	644	596	45	150	195	681	561	501
10	768	660	606	50	150	200	710	575	508
11	796	676	616	55	150	205	739	589	514
12	824	692	626	60	150	210	768	603	520
13	852	708	636	65	150	215	796	616	526
14	880	724	646	70	150	220	825	630	533
15	908	740	656	75	150	225	854	644	539
						Pair Gain Ratio:	4 to 1	6 to 1	8 to 1

TABLE 3
TYPICAL PCM CARRIER ADJUSTED ANNUAL COST

* See Table A-1, TE&CM 232.

** Annual charges for maintenance, depreciation, property tax, insurance, cost of money, margin, and income tax can be expressed as a percentage of investment for cables and electronics. The table assumes the total annual charges for an electronic channel is 1.25 that of a cable circuit.

D-66 LOAD COIL LOC.	PCM (24 CH./SYSTEM) SUBSCRIBER CARRIER FEEDER COST* PER CHANNEL			VOICE FREQUENCY LINE TREATMENT COST PER CIRCUIT			PCM SUBSCRIBER CARRIER ANNUAL COST ADJUSTMENT** PER CIRCUIT		
	PCM 48 CH. TER		96 CH.	LOAD			PCM 48 Channel Terminal		96 CH.
	1 Ter	2 Ter	1 Ter	COILS	LE/VFR	TOTAL	1 Ter	2 Ter	1 Ter
(a)	(b)	(c)	(d)	(e)	(f)	(g=e+f)	h=1.25(b-g)	i=1.25(c-g)	j=1.25(d-g)
1	438	438	426	0	0	0	548	548	533
2	454	448	436	0	0	0	568	560	545
3	470	458	446	15	0	15	569	554	539
4	486	468	456	20	0	20	583	560	545
5	502	478	466	25	0	25	596	566	551
6	518	488	476	30	0	30	610	573	558
7	534	498	486	35	0	35	624	579	564
8	550	508	496	40	150	190	450	398	383
9	566	518	506	45	150	195	464	404	389
10	582	528	516	50	150	200	478	410	395
11	598	538	526	55	150	205	491	416	401
12	614	548	536	60	150	210	505	423	408
13	630	558	546	65	150	215	519	429	414
14	646	568	556	70	150	220	533	435	420
15	662	578	566	75	150	225	546	441	426
				Pair Gain Ratio:			4 to 1	6 to 1	8 to 1

TABLE 4
TYPICAL PCM CARRIER ADJUSTED ANNUAL COST
(Continued)

D-66 LOAD COIL LOC.	REMOTE SWITCHING TERMINALS FEEDER COST* PER CHAN.				VOICE FREQUENCY LINE TREATMENT COST PER CIRCUIT			REMOTE SWITCHING TERMINAL ANNUAL COST ADJUSTMENT** PER CIRCUIT			
	32	64	128	256	LOAD COILS	LR/VFR	TOTAL	32 Lines	64 Lines	128 Lines	256 Lines
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h=f+g)	i=1.25(b-h)	j=1.25(c-h)	k=1.25(d-h)	l=1.25(e-g)
1	688	344	195	109	0	0	0	860	430	244	136
2	709	354	200	112	0	0	0	886	443	250	140
3	732	365	205	114	15	0	15	896	438	238	124
4	750	375	211	117	20	0	20	913	444	239	121
5	771	386	216	119	25	0	25	933	451	239	118
6	792	396	221	122	30	0	30	953	458	239	115
7	813	406	226	125	35	0	35	973	464	239	113
8	834	417	231	127	40	150	190	805	284	51	-79
9	854	427	237	130	45	150	195	824	290	53	-81
10	875	438	242	132	50	150	200	844	298	53	-85
11	896	448	247	135	55	150	205	864	304	53	-88
12	917	458	252	138	60	150	210	884	310	53	-90
13	938	469	257	140	65	150	215	904	318	53	-94
14	958	479	263	143	70	150	220	923	324	54	-96
15	979	490	268	145	75	150	225	943	331	54	-100
					Pair Gain Ratio:			5.3 to 1	10.7 to 1	21.3 to 1	42.7 to 1

TABLE 5
TYPICAL RST ADJUSTED ANNUAL COST

* See Tables A-1 and A-2, TE&CM 232.

** Annual charges for maintenance, depreciation, property tax, insurance, cost of money, margin, and income tax can be expressed as a percentage of investment for cables and electronics. The table assumes the total annual charges for an electronic channel is 1.25 that of a cable circuit.

2.4.2 For new cable construction the incremental cost per pair section is added from one DA to the next DA beginning at the CO to obtain the cost per physical circuit at each load point. For additions to existing plant, the installed cost per D-66 section is divided by the DA pair shortage. The DA pair shortage (PRS. SHORT) is equal to the DA circuit requirements (CKT. RQD.) pairs multiplied by a (FILL FACTOR) minus the existing pairs (EX. PRS.).

PRS. SHORT = (CKT.RQD. * FILL FACTOR) - EX. PRS. (Equation 1)

For part of a DA, multiply the fraction of the section by the cost for the section. This is usually necessary for branches and the half-section between the CO and the first load coil. Typical fill factors can be found in Table 9.

2.4.3 In Tables 2 through 5, the cost per channel for pair gain (carrier) equipment is based upon the assumption that the carrier systems are filled to capacity. It is also assumed that the equipment is applied in the minimum economical size terminal configuration, i.e. two eight-channel systems for grouped station carrier. If the subscriber densities (in a serving area) are such that less than two systems of grouped carrier can be used at a given location, the cost based upon one system should be used, substitute one system's costs from TE&CM 232 as appropriate, or distributed station carrier should be selected for the serving area. Typical costs for a range of PCM carrier and remote switching terminals are presented in Tables 3 through 5. The following factors control the selection of the pair gain system size:

2.4.3.1 The maximum pair shortage. If the maximum pair shortage was 23 pairs, a 96 channel PCM carrier system would not be selected to solve the shortage but rather a 24 channel system.

2.4.3.2 The cumulative subscriber quantity. Unless subscribers can be economically backfed into the terminal, the terminal capacity should be equal to or less than the cumulative subscribers (for pricing, not provisioning).

2.4.3.3 The number of subscribers in the serving area. This item is not as controlling as the first two items. It may be economical to connect more than one serving area into the carrier terminal by means of physical feeder circuits on the drop side of the terminal. The additional cost of the drop side feeder plant may be offset by the lower cost per channel (or line) of a larger installation. Example 2 includes procedures for comparing feeder plant to terminal size.

2.4.3.4 The length of the route. On very long routes it may be more economical to use more than one terminal location. The two and four (24 channel) terminal costs in Table 3 and the two (48 channel) terminal costs in Table 4 are included for multiterminal routes.

2.4.4 At each (CUM/DA) location the cost per carrier derived circuit is computed by adding the adjusted cost of a carrier channel from Tables 2 through 5 to the cost of physical circuit used to carry the carrier channel from the CO to the subscriber terminal. The latter cost is equal to the cost of a physical circuit times the number of pairs used for a system (or group) divided by the number of channels in the system.

2.4.4.1 The cost of a station carrier derived circuit (at a terminal) typically would be:

Adjusted cost per channel (Table 2) + Physical circuit cost
x $\frac{\text{1 pair/system}}{\text{8 channels/system}}$ = Cost/Circuit

In Figure 3b of Example 1 the cost per distributed station carrier derived circuit at location A6A is equal to:

$575 + ($722 X 1 ÷ 8) = $665

For grouped station carrier, it would be equal to:

$454 + ($722 X 1 ÷ 8) = $544

2.4.4.2 For one (24 channel) PCM carrier terminal the cost of a carrier derived circuit would be equal to:

Adjusted cost per channel (Table 3) + Physical circuit cost X
$\frac{\text{6 pairs/1 system}}{\text{24 channels/1 system}}$ = Cost/Circuit

The six (6) pairs are required since each system requires two pairs, the spare span line requires two pairs, and one pair is required for an order wire, and one pair for an interrogation pair (up to 11 repeaters, for longer systems see TE&CM Section 950). At A6A the cost would be equal to:

$783 + ($722 X 6 ÷ 24) = $964

2.4.5 The cost of a subscriber line concentrator derived circuit is computed in much the same method as a carrier derived circuit. The major differences are due to the type of circuit or trunk used to connect the central office and subscriber terminals.

2.4.5.1 One type of concentrator uses physical circuits as trunks to connect the terminals. Since physical circuits are used, a portion of the cost of load coils, loop extenders and voice frequency repeaters must be retained in the total circuit cost. The cost per concentrator derived circuit using physical circuits would be equal to:

(Installed cost per line - voice frequency treatment cost per physical line circuit) X carrier adjustment factor plus (physical circuit cost X trunks ÷ lines) = Cost/Circuit

Pair gain equals number of lines concentrated minus the number of trunks. From Table A-2 of TE&CM Section 232 the installed cost per concentrator line is $741 and 32 lines are concentrated over 8 trunks, at L.P. #6 the cost per circuit would be:

(($741 - $30*) X 1.25) + ($722 X 8 ÷ 32) = $1069

* From column g, Table 4.

2.4.5.2 The circuit cost for a concentrator using digital carrier as an integral part is computed in nearly the same manner as subscriber carrier. The major difference is that since the lines are concentrated, more lines share the same span line. The cost per circuit is equal to:

(Installed cost per line - voice frequency treatment cost per line) X carrier adjustment factor plus (cost per physical circuit X circuits per span line ÷ concentrator lines) = Cost/Circuit

From Table A-2 of Section 232, the cost per circuit at L.P. #6 would be:

(($800 - $30) X 1.25) + ($722 X 6 ÷ 32) = $1098

2.4.6 The circuit cost for an RST directly interfaced into a digital switch must also include a credit for CO line equipment. A credit is needed since the direct interface eliminates the need for CO lines. The RST feeder circuit costs in columns b, c, d, and e of Table 5 include a CO line credit (See Appendix, paragraph 2.6, TE&CM Section 232). The cost per RST line derived circuit would be equal to:

(Installed cost per line including CO line credit - voice frequency treatment cost per line) X electronic adjustment factor plus (physical circuit cost X trunks ÷ lines) = Cost/Circuit

From Table A-2 of Section 232, the cost per circuit at L.P. #6 for 32 lines would be equal to:

(($792 - 30) X 1.25) + ($722 X 6 ÷ 32) = $1088

2.4.7 The costs for the alternative facilities are shown above each load coil point and the break-even point is noted with an asterisk (*). Carrier should be used to serve subscribers beyond this point. Please refer to Figures 3a and 3b at the A4A and A5A pedestal locations.

2.4.8 The initial physical design should disregard existing station or subscriber carrier. The results will indicate whether the existing carrier might better be relocated.

2.5 Determining Cable Pair Requirements

2.5.1 The cable pair requirements are based on actual pairs needed. The pair requirements will include subscriber and trunk pairs, either physical or carrier. The total pair requirements are multiplied by a factor of 1.11 to insure that a maximum cable fill of 90 percent is not exceeded. If the result is greater than the number of existing pairs, there is a pair shortage.

2.5.2 The selection of a pair size for a new or reinforcement cable is based upon the growth rate in the design area and break-even year for placing a second cable (See Appendix 3). Table 6 contains a list of break-even years for the 24 gauge buried filled cables (average cost) listed in Table 1. The objective is to place a cable that is not exhausted due to growth until its break-even year (N) is reached.

2.5.2.1 The quantity of additional pairs (ADD. PRS.) needed is equal to the exhaust year pair requirements (EXH-YR. PRS. RQD.) times the growth rate (r) to the (N) years power minus the existing pairs (EX. PRS.).

$$\text{ADD. PRS} = \text{EXH-YR. PRS. RQD} \times r^{N} - \text{EX. PRS} \quad \text{(Equation 2)}.$$

2.5.2.2 If the five-year pair requirements (5-year PRS. RQD.) have been forecast, then the cable addition can be found using the equation:

$$\text{ADD. PRS} = \text{5-yr. PRS. RQD.} \times r^{(N-5)} - \text{EX. PRS.} \quad \text{(Equation 3)}.$$

Where (N) is the economic life in years from Table 6.

For example, a six-pair cable addition should last 22 years. If 9 pairs (5-year) are required in the design area and the growth rate is 6 percent (1.06) per year, and there is an existing six-pair cable, then in 22 years (or 17 years beyond the 5-year design period) the design area would require

$$9 \times 1.06^{(22-5)} - 6 = 18.2 \text{ additional pairs.}$$

The six-pair addition would have been exhausted before it should have been.

For a 12-pair addition to an existing six-pair cable in the same design area, the additional pairs would be equal to:

$$9 \times (1.06)^{(17-5)} - 6 = 12.1 \text{ additional cable pairs.}$$

The additional cable pairs in the design area should exhaust at the same time (in 17 years) as the economic life of the 12 pair cable addition.

CABLE	ECONOMIC LIFE YEARS (N)
BFC 6 - 24	22
BFC 12 - 24	17
BFC 18 - 24	16
BFC 25 - 24	16
BFC 50 - 24	12
BFC 75 - 24	11
BFC 100 - 24	7
BFC 150 - 24	3
BFC 200 - 24	2
BFC 300 - 24 and above	1

TABLE 6
BREAK-EVEN YEARS FOR VARIOUS CABLE SIZES

2.5.2.3 Table 7 is based upon Equation 2. It is used in cases where the exhaust date (90% fill) of the existing plant is known. The cable addition is found at the point of intersection of the existing cable and the cable pairs required at the exhaust year.

2.5.2.4 Table 8 is based upon Equation 3. It is used in designs based upon five-year cable pair requirements. It is assumed that the cable construction will be completed at the beginning of the five-year period.

2.5.2.5 Table 9 is for use in cases of new and total replacement construction. It is used in conjunction with the five-year cable pair requirements. It is the same as the 0 (zero) existing pair column in Table 8. Using the total pair requirements consult Table 9 for the proper fill factor for the type growth area involved. This factor times the pair requirement equals the cable pairs needed including spares. The table takes into account present worth of annual charges and delays larger cables. The factors developed were based on current data. It should be periodically reviewed and updated with the then current data using the method in Appendix 3.

2.5.2.6 In a computer-aided design, a subroutine could be written that steps through the cable sizes until the proper size is found. The routine would start with the smallest size cable (6 pairs), plug its break- even year and the other variables (growth rate, etc.) into the equation (2 or 3) and test the six pair cable. If the six pair is satisfactory, the subroutine would return to the main program. If it is not, the subroutine would select and test the next larger size (12) and continue until a suitable pair size is found.

2.6 Other Design Considerations

2.6.1 Of major importance is the available space for placing cables in the ground or on existing pole lines. Revised tables should be prepared to cover additional costs due to such problems.

2.6.2 Delay a cable addition if it is only for providing spare pairs.

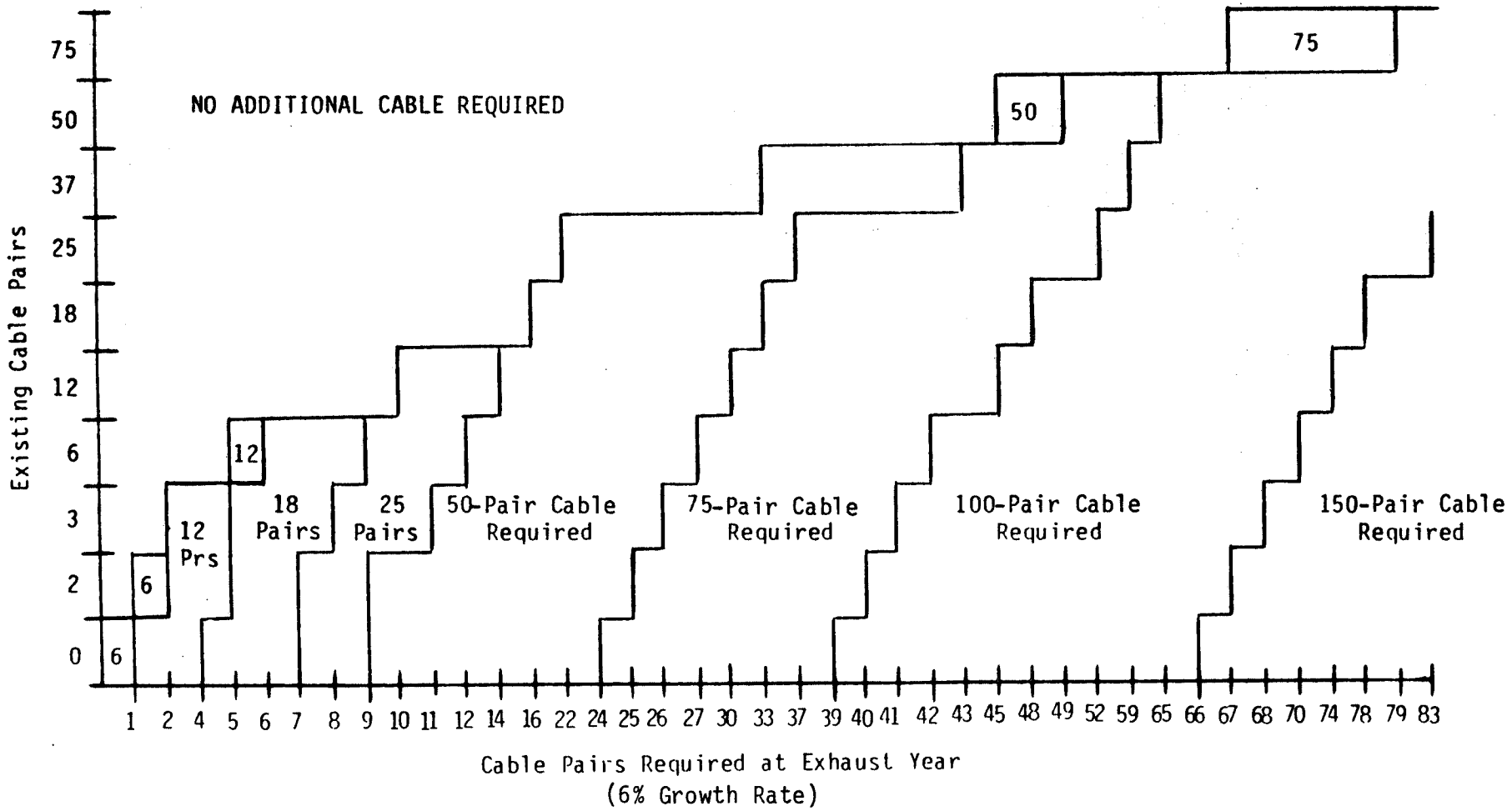
2.6.3 The minimum plant addition should be six pair cable.

2.6.4 Distributed station carrier should be used mostly to delay an addition of some length to an existing small cable or for very sparsely populated areas.

2.6.5 In sparsely populated areas, consideration should be given to providing distribution pairs both ways from an SAI, thus doubling the size of the serving area. This is especially true in the carrier service area. Cable pairs are often available in such instances. This reduces the number of carrier systems, improves their fill and reduces interfaces.

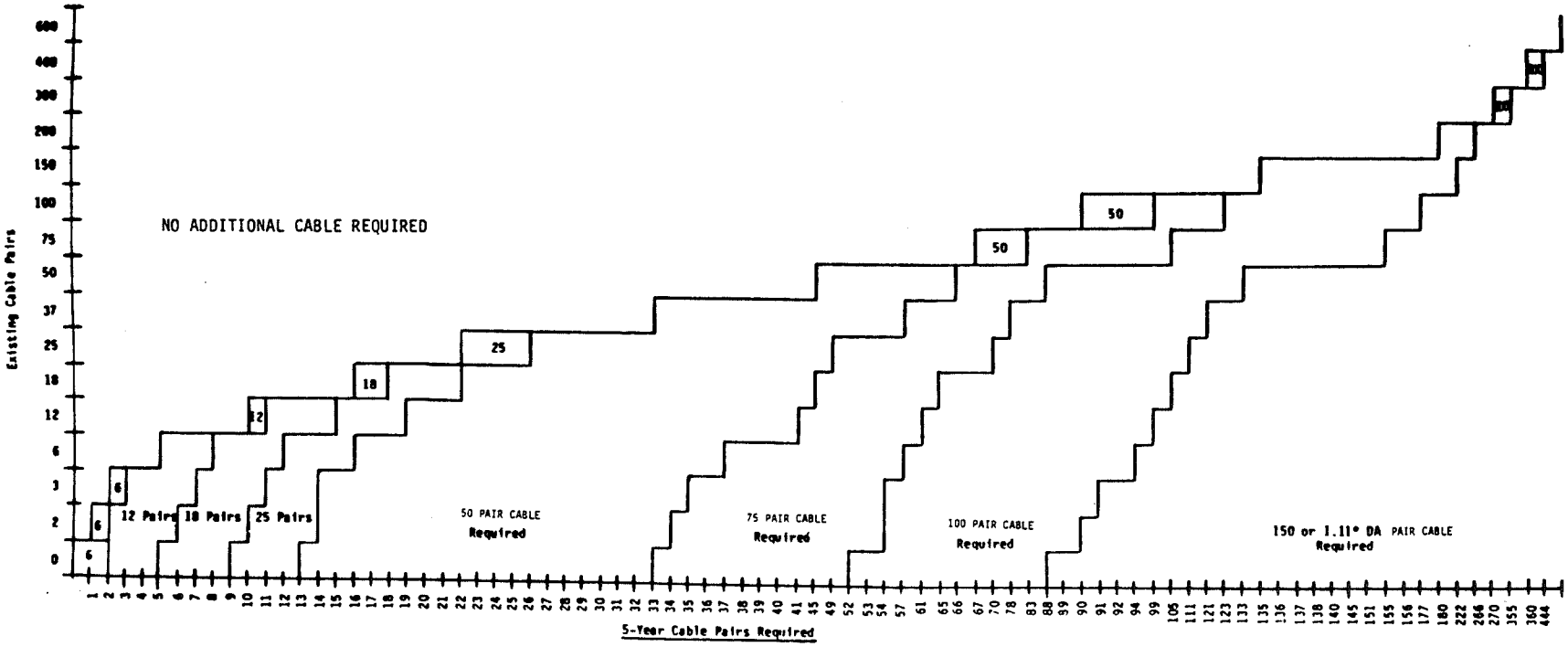
2.6.6 For small SAI's where an existing pedestal is adequate, plan to retain the pedestal.

CABLE ADDITION SELECTION CHART
BASED ON EXHAUST YEAR
TABLE 7



CABLE ADDITION SELECTION CHART
BASED ON 5-YEAR PAIRS

TABLE 8



(6% Growth Rate)

5-YR CIRCUITS* REQUIRED	GROWTH RATE**		
	LOW (2%)	MEDIUM (6%)	HIGH (8%)
1 - 3	1.40	2.70	3.70
4 - 6	1.27	2.00	2.52
7 - 14	1.24	1.90	2.33
15 - 22	1.22	1.79	2.16
23 - 35	1.15	1.50	1.71
36 - 44	1.15	1.42	1.59
45 - 62	1.13	1.42	1.59
63 - 67	1.13	1.42	1.49
68 - 90	1.11	1.12	1.17
91 or more	1.11	1.11	1.11

TABLE 9
TYPICAL FILL FACTORS FOR NEW
OR TOTAL REPLACEMENT CONSTRUCTION

* Number of five-year subscribers X appropriate growth rate fill factor = mininum number of pairs required.

** A growth rate should be used along each route which reflects the growth along that route, irrespective of growth on other routes.

For further information and the method used to develop cable fill percentages, see Appendix 3.

3. DESIGN PROCEDURE

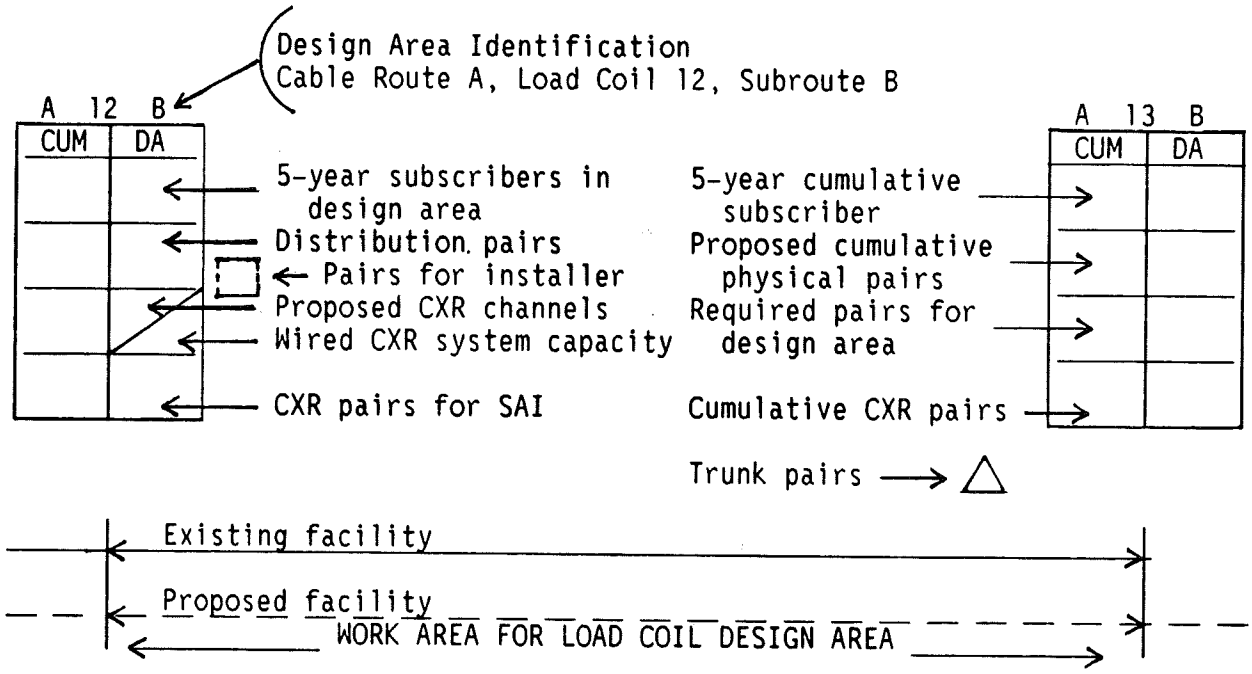
3.1 Predesign Stage.

3.1.1 Obtain current cable data. Arrange cable cost data in the format of Table 1. The cost per section will be used in calculating both physical and pair-gain circuit costs. If new construction is proposed, calculate the incremental cost per pair section.

3.1.2 Develop electronic cost tables as outlined in paragraph 2.3 using current costs. These costs will be used in calculating pair-gain circuit costs.

3.1.3 Calculate cable economic exhaust life (break-even year N) using the method explained in Appendix 3. Develop cable addition selection tables using equations 2 or 3 (see paragraph 2.5). The break-even years and selection tables should be developed on a company or regional basis and be reviewed periodically. They are developed using cable costs which are dependent not only on national economic conditions but also on local economic and geographic conditions and vary considerably with time.

3.2 Block Identification Information.



3.3 Phase I: Locate the load coils and any major subroute where an SAI is proposed. Show the CUM-DA blocks for each, as above; show the five-year subscribers for the load coil area (Design Area) in the DA block, and the existing retainable facilities as a solid line under the blocks. Next accumulate the five-year subscribers and show them in CUM block; show the trunk pairs (if any) in a triangle under the CUM block and determine the required pairs needed. Determine what growth rate will be used on each route or area. (A medium growth rate was used for all the examples.) Determine pair shortages using a maximum fill of 90 percent. Using Table 7 or 8 select the cable addition needed for an all physical plant. Determine the cost per physical circuit to each load point, the carrier cost for each load point, and put these figures over the block identification number. For additions to existing plant, the cost per circuit is equal to the cost per section divided by the pair shortage (90% fill). For new construction, the cost per circuit is equal to the incremental cost per pair section. Mark the break-even point for the carrier with an asterisk (*).

In Figure 2 permanent and temporary break-even points are shown. The permanent break-even (PBE) point is the point beyond which feeder circuits will be derived using pair gain equipment. In cases of new and total rebuild construction the PBE point will be found in Phase I using the incremental cost per pair. The temporary break-even (TBE) point applies to cases in which the existing facilities can support pair gain equipment. Feeder circuit shortages beyond the TBE point are economically relieved using pair gain equipment located at an SAI beyond the TBE. Feeder circuit shortages inside the break-even point are relieved with cable additions. Note: If the pair gain equipment is located at the TBE, not only would the shortage beyond the TBE point not be relieved, but the pair gain equipment would be used to uneconomically relieve the shortage inside the TBE.

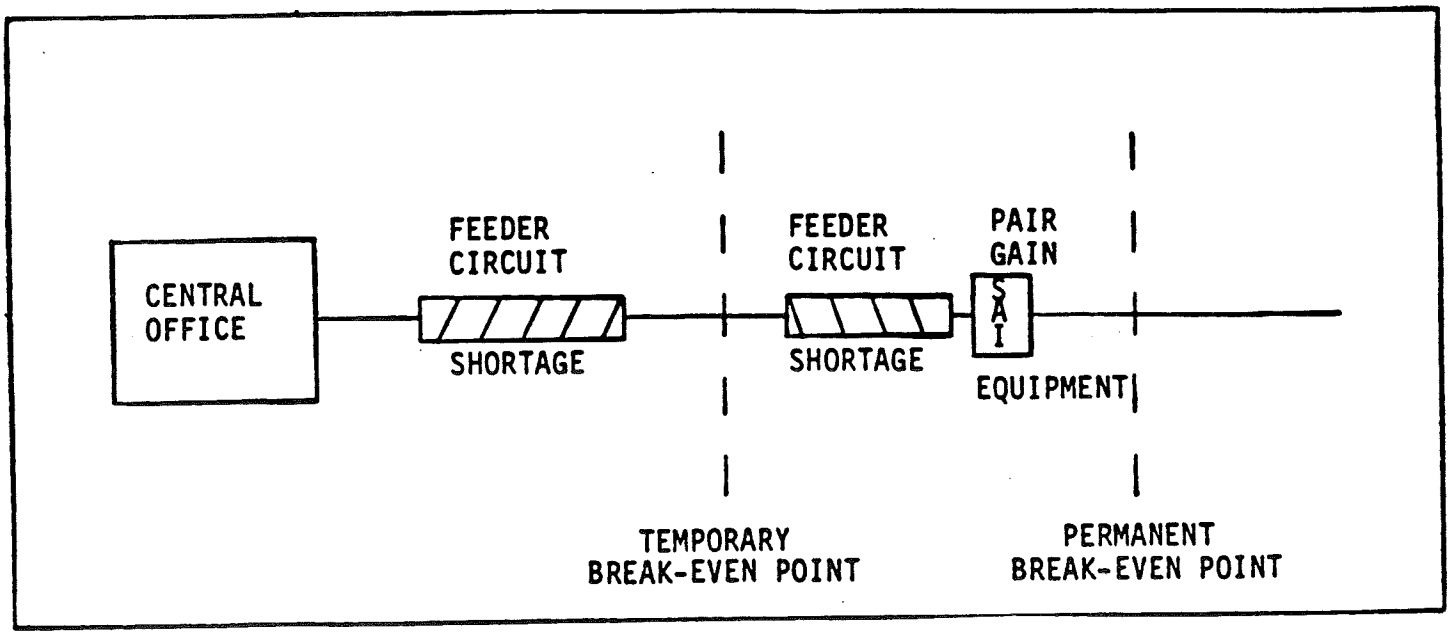


FIGURE 2

Note: If no carrier is proposed, go to Phase III after Phase I and disregard carrier information and the recalculation of new cable sizes. Only locate the SAI's and show the distribution and feeder pairs.

(See Phase I Drawing, Figures 3a-f and 6a-f, Example 1; Figures 10a-d, Example 2.)

3.4 Phase II: Determine appropriate carrier types and locations to use beyond the break-even points. Fill the systems as much as possible. When they have been located, mark them as Serving Area Interface (SAI) points over the identification block. Beginning at the far end, show the distribution pairs to each SAI in the distribution pair DA block, the carrier channels required over the design system capacity for the SAI in the DA block. Show the carrier pairs needed in the bottom DA block for the systems at this SAI. Using the regular fill factors, determine whether extra carrier pairs are needed beyond the five-year period for future growth. On the CUM side of the SAI block show the total carrier pairs needed in the cumulative carrier pair block. Show the pairs, if any, for serving sub- scribers on a physical basis. Show the total circuits needed in the CUM block. Reduce the cable additions needed due to the carrier service.

Since the carrier channels wired but not equipped are available generally only at the SAI involved, they are shown only there. To check subscribers served by carrier at any point, deduct the physical feeders from the CUM subscribers. It is suggested that equipped and wired channels be shown at the CO for each route.

(See Phase II Drawing, Figures 4a and 7a-d, Example 1; Figures 11a&b, Example 2a.)

3.4.1 The backfeed method: This may be used for sparse areas to fill grouped carrier systems and reduce the number of SAI's. It may also be employed for digital carrier systems to reduce the number of installations;

however, care must be exercised that the backfeed portion is not too long and thus become uneconomical.

Locate the SAI's such that subscribers are served both ways from the carrier location. Use an arrow from the DA block to the CUM block in the design areas toward the CO to indicate a backfeed. Show the subscribers or distribution pairs needed forward from the SAI in the DA block forward from the SAI. The carrier channels needed will be this figure plus those in the distribution block at the SAI. The cable requirements forward from the SAI will be based on the carrier pairs plus the distribution pairs needed on the backfeed in the DA block in the normal manner.

(See Phase III Drawing, Carrier Backfeed Method, Figures 13a-c, Example 2b.)

3.5 Phase III: Complete the design inside the break-even point beginning at the SAI where the nearest carrier installation is proposed. Accumulate the carrier pairs with all branches into the office. Locate the fourth load point from the CO and show SAI's here and at every other load point out to the break-even point. Inside the fourth load point nonloaded pairs are used, so locate any SAI's for the benefit of the installer paying special attention to subscriber densities and to junctions of routes. Show the distribution pairs needed in the DA block at each SAI. Show the total circuit requirements in the CUM block. Recalculate the new cable sizes needed between load points if carrier is used.

(See Phase III Drawing, Figures 5a&b and 8a-c, Example 1; Figures 12a-c, Example 2a and Figure 14a, Example 2b.)

3.6 Phase IV: Review the cable additions. Consider delaying additions providing only spare pairs. Consider changes in cable sizes to better use the cable plant where such changes are not too costly. Show the pairs to be available to the installer at each SAI. Show the housing type above the SAI block. Reserve at least 10 percent of the total cable pairs for present and future carrier pairs if any carrier installations are proposed on a cable route.

(See Phase IV Drawing, Figures 9a-f, Example 1; Figures 15a&b, Example 2b.)

3.7 Detailed examples. Two detailed examples of the SAVE design method are provided in Appendices 1 and 2. They consist of the following components.

	APPENDIX 1 EXAMPLE 1	APPENDIX 2 EXAMPLE 2
Typical Outside Plant Cost Data	Table 1	Table 1
Typical Station Carrier Adjusted Annual Cost	Table 2	Table 2
Typical PCM Carrier Adjusted Annual Cost	Table 3	Table 3&4
Typical RST Carrier Adjusted Annual Cost	--	Table 5
Typical Cable Addition Selection Chart	Table 8	--
Typical Fill Factor	--	Table 9

	APPENDIX 1 EXAMPLE 1	APPENDIX 2 EXAMPLE 2		
SAVE WORKSHEETS				
Phase I	Figures 3a-f	Figures 10a-d		
Preliminary Phase II	Figure 4a	---	--	
Preliminary Phase III	Figures 5a&b	---	--	
			2a	2b
Revised Phase I	Figures 6a-f		--	--
Phase II	Figures 7a-d	Figures	11a&b	--
Phase II (Backfeed Methods)	--	Figures	--	13a-c
Phase III	Figures 8a-c	Figures	12a-c	14a
Phase IV	Figures 9a-f	Figures	--	15a&b
SUPPLEMENTAL WORKSHEETS				
Cable Additions - Phase I	Figure 3g			
Physical Feeder Circuit Cost Phase I	Figure 3h			
Carrier Feeder Circuit Cost Phase I	Figure 3i			
Carrier Placement - Phase II	Figure 7e			
Cable Additions - Phase II	Figures 4b, 7f&g			
Cable Additions - Phase III	Figures 5c & 8d			

APPENDIX 1

ADDITIONS TO EXISTING PLANT
(EXAMPLE 1)

This example presents a detailed step-by-step illustration of the four phases of a SAVE design for the situation where an addition to existing cable plant is required.

PHASE I: Initital physical requirements, refer to Figures 3a thru 3f. (Use Table 8.) The work area is between vertical (center) lines of load blocks. Put five-year subscribers into DA blocks and accumulate in CUM blocks. Note that at cable branch points the CUM quantity is equal to the total of all subscribers up to the branch point. For example, in Figure 3d the CUM quantity at A10.4A is equal to the sum of the CUM quantities of A11A (16) and A11P (3) plus the DA quantities of A10.4A (4) and A10.4P (0) or 23. A solid line (or lines) representing existing facilities is placed below the CUM/DA blocks. List existing cables above the solid line. Cable additions are placed below as a dashed line.

Calculate cable additions.

Cable addition between A8A and A8.7A: Requirements = 91 from CUM at A8.7A and 7 from DA at A8A = 98 X factor of 1.11 (10% maximum fill) = 109 needed including spares less 100 existing = a 9 pair shortage. Consult Table 8. Ninety-eight five-year circuits and 100 pairs existing requires a 50 pair cable addition. A8.7A to A9F = (16 + 0) X 1.11 = 18. 18 - 18 = 0. No cable addition required. A8.7A to A9A = 40 from CUM at A9A plus 3 from DA at A8.7A = 43 needed X 1.11 = 48 which is less than existing 50 pair cable = 0 pair shortage. No cable addition required. See Figure 3c. See Figure 3g for sample worksheet.

Calculate feeder circuit costs.

Cost of physical circuit at A8.7A = $1201 at A8A + .7 X $5151 for a 50 pair, 24 gauge, cable addition (Average Cost, Table 1) - 9 (5-year 90% maximum fill) pair shortage = $1602. At A9A = $1602 at A8.7A + 0 (no shortage - addition not required) = $1602. At A9F = $1602 at A8.7A (A) + 0 = $1602. See Figure 3c. See Figures 3h and 3i for sample worksheets.

Cost of distributed station carrier at A9A = $419 (Table 2) + $\frac{\$1602}{8}$ = $619.

Cost of grouped station carrier at A9A = $298 (Table 2) + $\frac{\$1602}{8}$ = $498.

Cost of PCM subscriber carrier at A9A = $681 (1 System*, Table 3) + $1602

X $\frac{6}{24}$ = $1082.

* Since the maximum pair shortage is 28 (between A3A and A4A) on route A and 25 (between A5.3C and A6C) on route C, the PCM carrier costs are based upon a single system (24 channels). To solve a 28 pair shortage one full system and a partially filled second system would be required. The two systems would require 8 pairs (including 2 pairs for a spare span line). To provide a net pair gain of 28 the two systems would be equipped with a total of 36 channels (28 for the shortage and 8 to 'free-up' metallic pairs for the span lines). The per circuit costs of the partial filled systems would be higher than that of two filled systems and possibly higher than one filled system.

PHASE II: Design Beyond Carrier Temporary Break-even Point (TBE). Referring to Figures 3a thru 3f, consider using distributed station carrier at load point A5A and beyond on the A route. The 90 percent fill pair shortages on the A route are less than 16 (two full systems of grouped station carrier) beyond A7.3A. The projected circuit shortages (100%) are 10 or less on the A route which means that 36 percent of the carrier equipment is planned as a safety factor but need not be installed. On the D route the 90 percent fill shortage is three or less. The 100 percent fill shortage is 0. Therefore, distributed station carrier would be the choice on the D route. On the L route the shortages are small; therefore, consider using distributed station carrier on the L route. Consider using PCM carrier on the C route. There is a concentration of subscribers in the A12C design area. The shortages are continuous between A5.3C and A12C. The maximum 90 percent fill pair shortage is 25 in the A5.3C design area. The maximum 100 percent fill shortage is 18 in the A6C design area which is equal to the net pair gain of a single PCM carrier system (24 channels - 6 span line pairs). Consider placing the PCM terminal at A12C. A12C has the last CUM subscriber quantity that is higher than 24. There are 21 subscribers in its design area. Begin redesign of cable plant by starting with the PCM terminal at A12C. This terminal will have the greatest effect on the design of the system . Prepare a preliminary Phase II design for the plant beyond the PCM carrier break-even point at A9C. The maximum pair shortage, 20 beyond A9C occurs in the A9C design area. Twenty is greater than the net pair gain for one PCM system (24 - 6). Therefore, two systems will be required. Sixteen cable pairs are available in the A9C design area (90% of 18). Calculate the equipped carrier channels: 16 minus 8 for the span line leaves 8 for distribution and feeder. Thirty-four CUM subscribers minus 8 equals 26 equipped carrier channels. Referring to Figure 4a, show 26 equipped carrier channels over a capacity of 48 wired channels. Show eight carrier pairs in the DA and CUM blocks. Show distribution pairs in the DA block and the feeder and required pairs in the CUM block. For example, between A11C and A12C 3 distribution pairs + 0 physical feeder pairs + 8 carrier feeder pairs = 11 required pairs. Recalculate pair shortages, A11C to A12C: 11 X 1.11 = 13 is less than 18 existing; no shortage. Redesign cable additions using Table 8, see Figures 4a and 4b.

PRELIMINARY PHASE III: Preliminary design inside of route C break-even point, Figures 5a & 5b. Locate SAI's. Show carrier pairs in CUM blocks inside the

break-even point. Show distribution pairs and feeder pairs at each SAI. SAI is located at A2.6A&C, since it is a major cable route branch and at A4C, A6C, and A8C, since they are load coil points. Compute and show required pairs. Required pairs for design area A8C = 6 feeder + 5 distribution + 8 carrier feeder = 19 in A9C CUM block. Recompute pair shortage: 19 X 1.11 = 22 is less than 25 existing; no shortage. Cross out 50 pair addition. See Figure 5c for other locations.

REVISED PHASE I: Revise Phase I based upon having a carrier terminal at A12C. Note that the pair shortage between AOA and A1A has been relieved. This eliminates the cable addition and its cost which in turn reduces the physical feeder circuit cost and increases the distance between the central office and the break-even points. However, on the C route the pair shortages are reduced without reducing the cable sizes. This causes the physical circuit cost to increase and the break-even point to move toward the central office. See Figures 6a thru 6f.

PHASE II: Design beyond the break-even point, refer to Figures 7a-7g. On route A, the pair shortages beyond the break-even point,(A8A), are too small to justify the use of PCM or grouped station carrier. The same is true for the L and D routes. On the C route the choice would be between using distributed station carrier or backfeeding into the PCM carrier terminal at A12C. Since one distributed carrier system could serve both the L and C routes, use it instead of backfeeding into A12C.

PLACEMENT OF DISTRIBUTED STATION CARRIER: Worksheets similar to Figures 7e and 7f are useful in sizing and locating distributed station carrier systems. Starting with tail end CUM/DA block of each individual route multiply the existing cable pairs by the appropriate cable fill percentage. Referring to Figure 7e, at location A10.4A the result is that 16 pairs are available for five-year subscribers as shown in column (d). The remaining two pairs are held in reserve for unforeseen growth, replacement of bad pairs and other future operating needs. At this point a summation of the required pairs is made. The number of pairs needed for feeder circuits (physical or carrier), for preceding DA sections (physical or carrier) for the five-year subscribers in the current DA, plus one more pair each time an additional distributed station carrier system is required, are added together and the sum is subtracted from the available pairs. The result in column (j) is the pair shortage for that DA. Summing the DA subscribers (column i) and the pair shortage (column j) determines the number of DA subscribers that can be served by physical pairs (column k) with the provision this number is never negative. A negative number is changed to a zero value. The number of DA subscribers served by distributed carrier is simply the DA subscribers (column i) minus the number of physical pairs (column k). In the case of A10.4A the pair shortage (j) is greater than the number of DA subscribers (i). All available pairs have been assigned as feeders to A11.7A or distribution pairs in A11A. Therefore, it is necessary to return to A11A, take one of the available pairs for the carrier system and place one of the DA subscribers on a distributed carrier channel.

From a SAVE design viewpoint a distributed carrier system should be treated as a cable with a number of distribution pairs equal to the number of channels

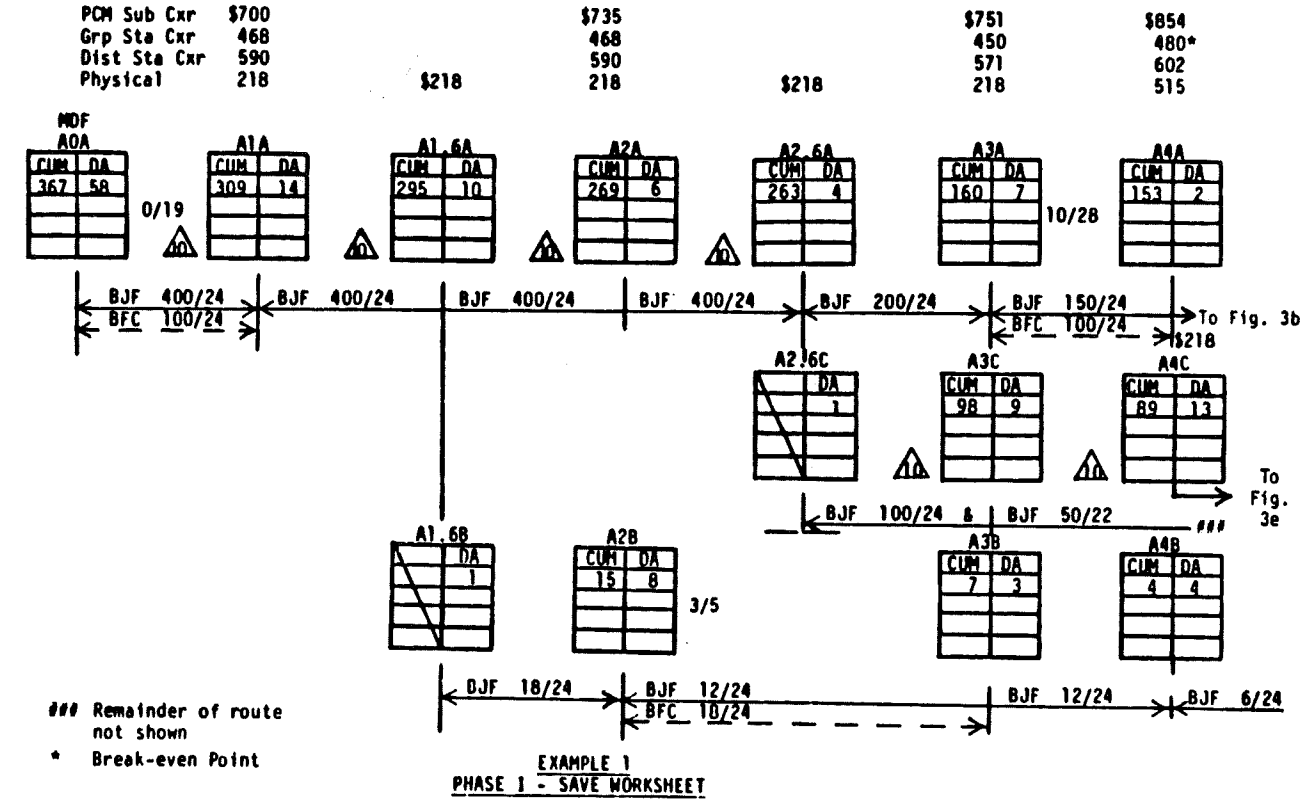
per system. Channels should be dedicated in specific design areas in the same manner as distribution cable pairs. The carrier system can serve any number of serving areas and is only limited by the number of channels per system. The systems are typically limited to one branch between repeaters. To speed up the design process separate systems are allotted to each of the major cable branches (A, D, E, F, and G). If possible, they will be consolidated later in Phase IV.

To keep track of subscribers on physical or carrier distribution circuits, the ones on physical circuits are indicated in parentheses on Row 2 of DA block and the ones on carrier are indicated on Row 3. In SAI blocks the sum of the physical distribution circuits is indicated by Row 2. The sum of the carrier circuits (channels equipped) is indicated at an SAI when a system is exhausted or the break-even point is reached.

RECALCULATE CABLE ADDITIONS: The numbers generated from the carrier location process are then transferred to the SAVE worksheets in Figures 7a, 7b, 7c, and 7d. These new numbers are then used to determine what the revised cable requirements are. For example, using a worksheet similar to Figure 7g, at location A10.4A the required pairs are five distribution pairs from A11A, one carrier pair and physical feeder pairs from the SAI at A11.7A for a total of 16 pairs. Multiplying by a fill factor of 1.11 gives a requirement for 18 pairs in the cable. The existing cable at that point has 18 pairs so no new cable is required. Cross out the 15 pair cable addition proposed in Phase I. Follow the same process for all DA locations.

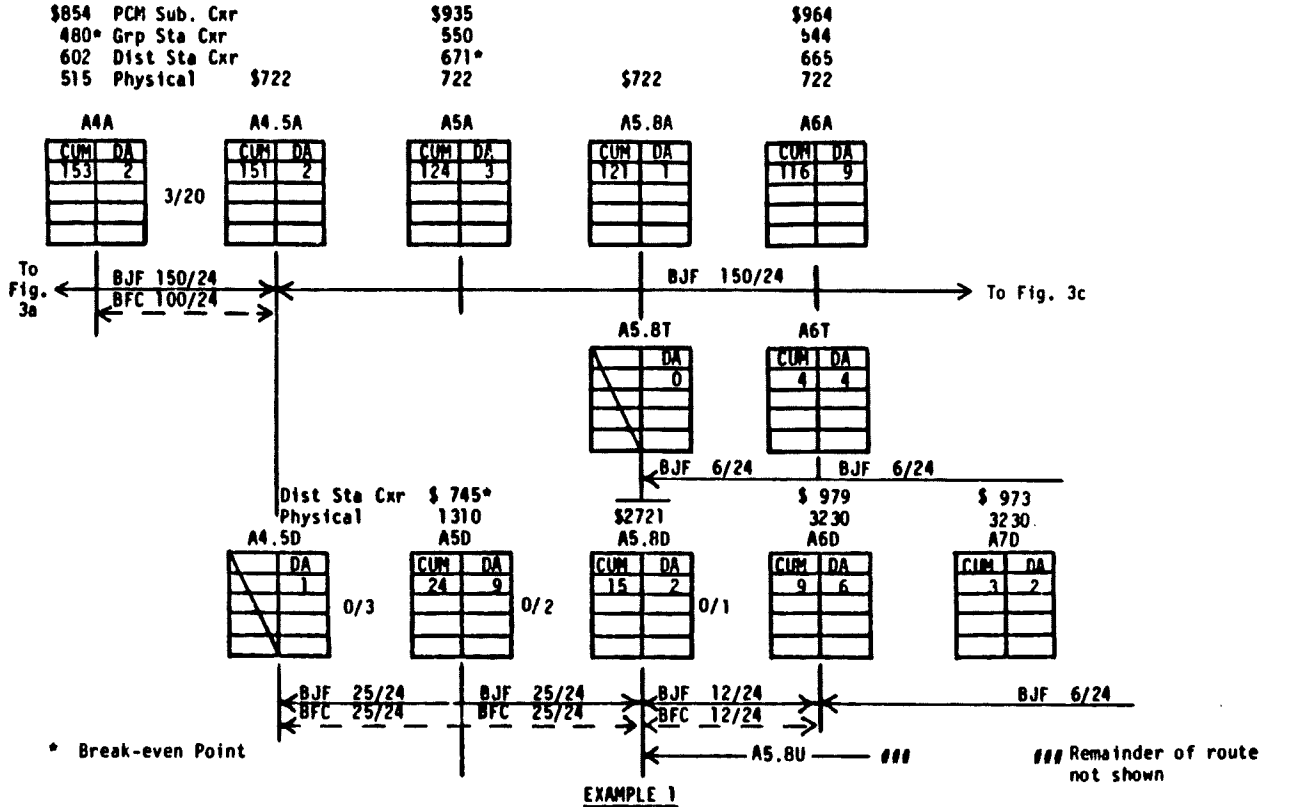
PHASE III: Design inside carrier break-even point, Figures 8a-c. Locate SAI's at load coil points, major branches or other desirable DA's. Show carrier pairs in CUM block inside the break-even point. Show distribution pairs and feeder pairs at each SAI. SAI is located at A2.6A, since it is a major cable route branch. At A4A, since it is the first point where loading is required and at A5.8A and A7.3A since they are cable branch points. Compute and show required pairs using a worksheet similar to 8d. For example, the required pairs for design area A7.3A = 75 physical feeders and 3 carrier feeders from A8.7A + 10 distribution pairs = 88. Eighty-eight X 1.11 = 98 (less than 100 existing) = no shortage. Cross out BFC 75-24 cable addition.

PHASE IV: Engineering judgment changes, pairs for installer and type housing at SAI's. Consider deleting 18 pair cable addition between A1.6B and A2B. Single channel carrier can be used for additional circuits. Consolidate the distributed carrier systems, the A route's with E route's and F route's with the D route's system. Note that the 100 pair addition between A4A and A4.5A is now no longer required. Delete BFC 100-24 between A3A and A4A and BFC 50-24 between A7A and A7.3A since they are needed only for spare pairs. Additional spare pairs can be provided by planning for a carrier system in the A11.7A serving area. All physical pairs available to the installer are indicated outside of the distribution pair block. Distributed carrier channels available to the installer are indicated below. Show pairs reserved for carrier outside of distribution block. Consider using screened cables for new feeder cable installations. See Figures 9A thru 9f.



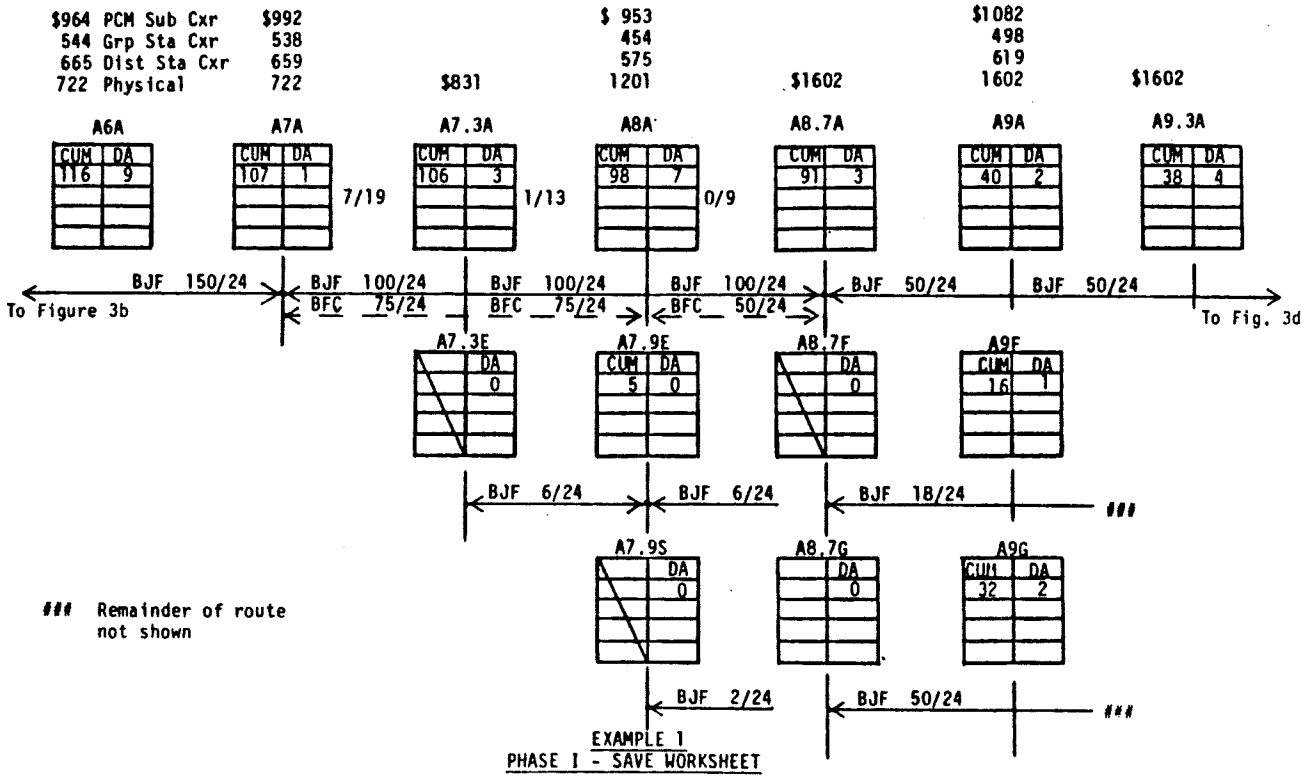
EXAMPLE 1
PHASE 1 - SAVE WORKSHEET

FIGURE 3a



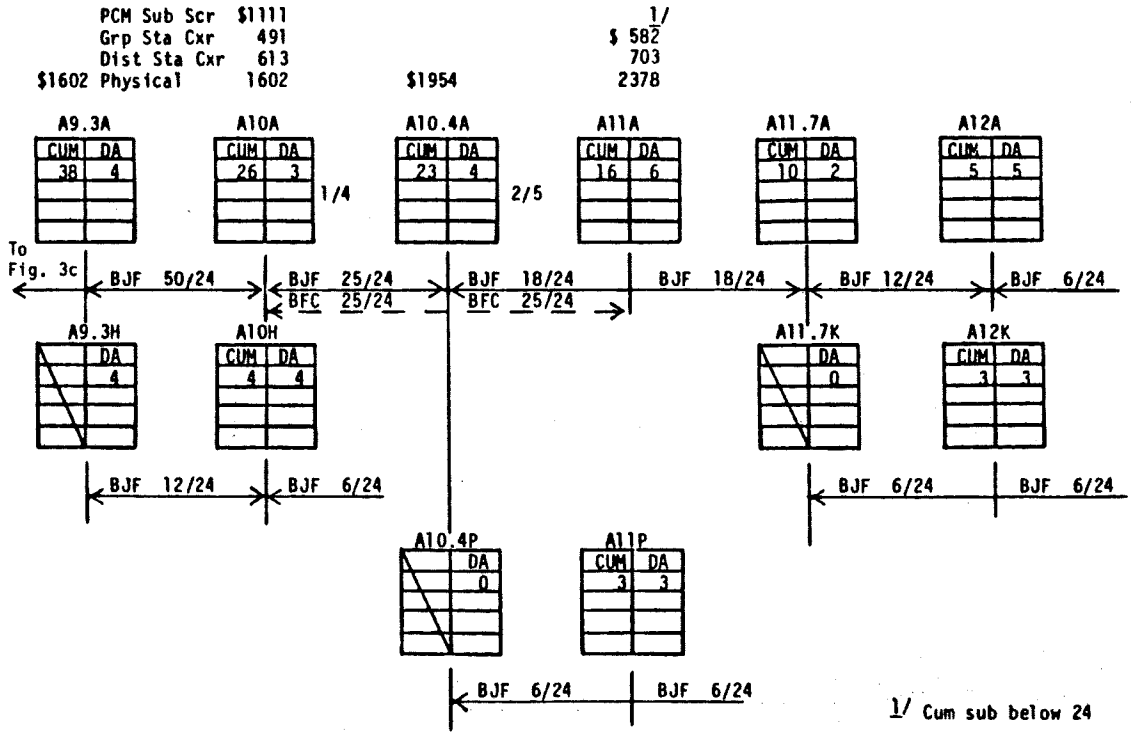
EXAMPLE 1
PHASE 1 - SAVE WORKSHEET

FIGURE 3b



EXAMPLE 1
PHASE I - SAVE WORKSHEET

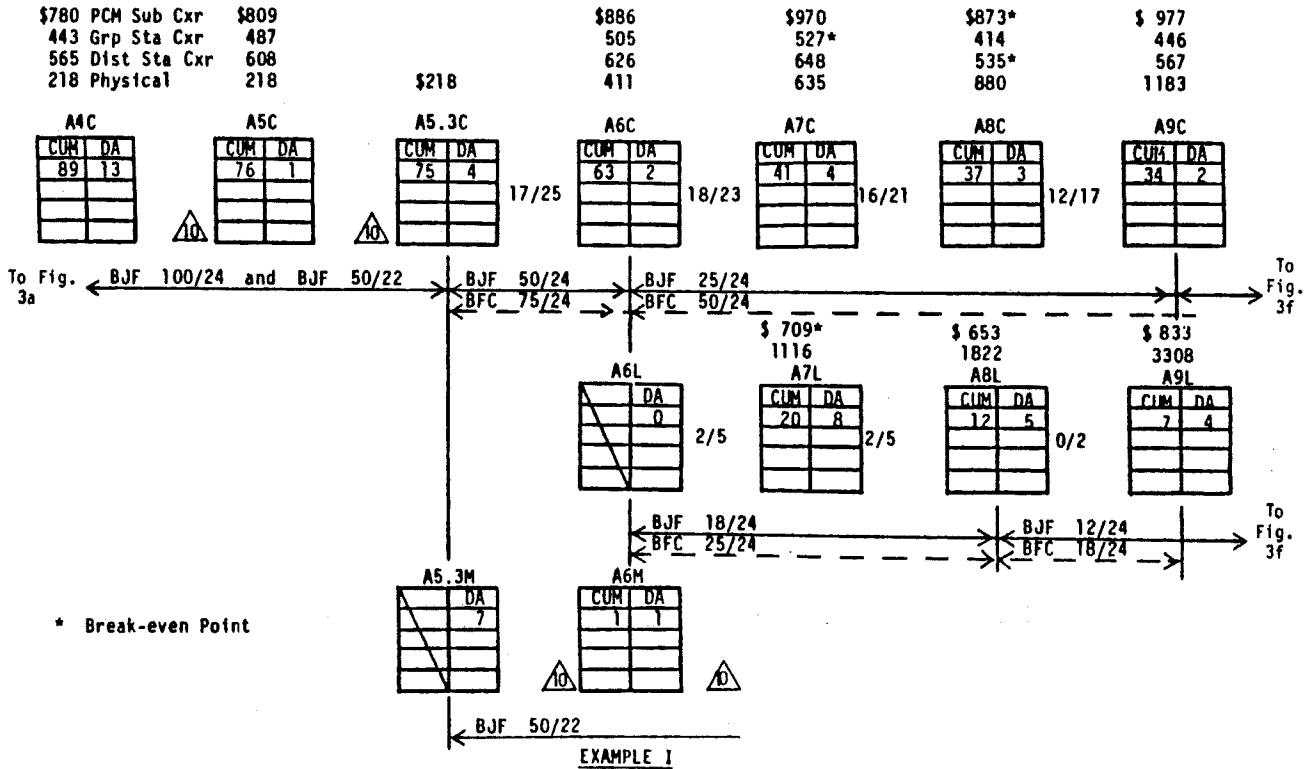
FIGURE 3c



1/ Cum sub below 24

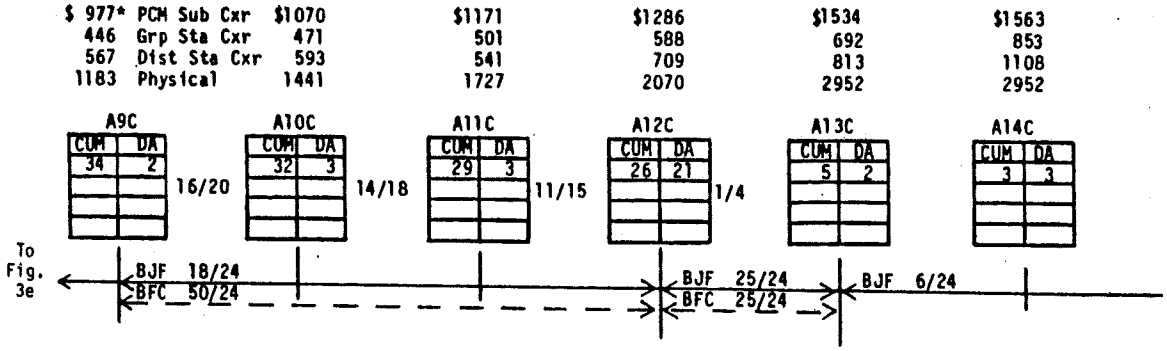
EXAMPLE 1
PHASE I - SAVE WORKSHEET

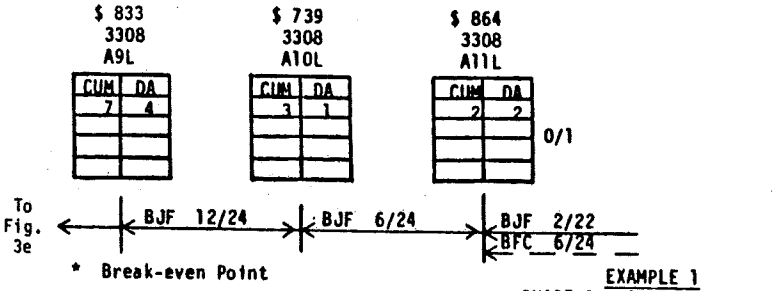
FIGURE 3d



EXAMPLE I
PHASE I - SAVE WORKSHEET

FIGURE 3e





EXAMPLE 1
PHASE I - SAVE WORKSHEET

FIGURE 3f

Work Area		DA Subs	Preceding CUM Quantity	5-Year Trunk Circuits Required	Total 5-Year Circuits Required	Required Pairs for Design Area	Existing Facility Pair	100% Fill Pair Shortage	90% Fill Pair Shortage	Cable Additions (Table 8)
(a)	(b)	(c)	(d)	(e)	(f=c+d+e)	(g=fX1.11)	(h)	(i=f-h)	(j=g-h)	
A12A	-end-	5	0	0	5	6	6	-0-	-0-	None
A11.7A	A12A	2	5	0	7	8	12	-0-	-0-	None
A12K	-end-	3	0	0	3	4	6	-0-	-0-	None
A11.7K	A12K	0	3	0	3	4	6	-0-	-0-	None
A11A	A11.7A	6	10	0	16	17	18	-0-	-0-	None
A10.4A	A11A	4	16	0	20	23	18	2	5	25
A8.7A	A9A	3	40	0	43	48	50	-0-	-0-	None
A8.7F	A9F	0	16	0	16	18	18	-0-	-0-	None
A8.7G		0	32	0	32	36	50	-0-	-0-	None
A8A	A8.7A	7	91	0	98	109	100	-0-	9	50
A7.3A	A8A	3	98	0	101	113	100	1	13	75
A2B	*	8	7	0	15	17	12	3	5	18
A1.6B	A2B	1	15	0	16	18	18	-0-	-0-	None
A1A	A1.6A	14	295	10	319	355	400	-0-	-0-	None
AOA(MDF)	A1A	58	309	10	377	419	400	-0-	19	100

SAMPLE CALCULATION OF PAIR SHORTAGES AND CABLE ADDITIONS

SUPPLEMENTAL WORKSHEET - PHASE I

FIGURE 3g

Design Area	Cost of Preceding Section	Design Area Cable	Cost Per Section	Length (4.5kft=1)	90% Fill Pair Shortage	DA Cost	CUM Ckt. Cost	CUM Location
(a)	$ (b)	(c)	$ (d)	(e)	(f)	(g=d*e+f)	(h+b+g)	(i)
AOA	0	BFC 100-24	8300	.5	19	218.42	218.42	A1A
A1A	218.42	None	-	.6	-	-0-	218.42	A1.6A&B
A1.6A	218.42	None	-	.4	-	-0-	218.42	A2A
A2A	218.42	None	-	.6	-	-0-	218.42	A2.6A&C
A2.6A	218.42	None	-	.4	-	-0-	218.42	A3A
A3A	218.42	BFC 100-24	8300	1.0	28	296.43	514.85	A4A
A7A	722.35	BFC 75-24	6875	.3	19	108.55	830.90	A7.3A&E
A7.3A	830.90	BFC 75-24	8675	.7	13	370.19	1201.09	A8A
A8A	1201.09	BFC 50-24	5151	.7	9	400.63	1601.73	A8.7A,F&G
A8.7A	1601.73	None	-	.3	-	-0-	1601.73	A9A
A11A	2377.67	None	-	.7	-	-0-	2377.67	A11.7A&K
A11.7A	2377.67	None	-	.3	-	-0-	2377.67	A12A
A12A	2377.67	None	-	< 1.0	-	-0-	2377.67	END
A1.6B	218.42	None	-	.4	-	-0-	218.42	A2B
A2B	218.42	BFC 18-24	2972	1.0	5	594.40	812.82	A3B
A3B			Rest of Route Not Shown					
A2.6C	218.42	None	-	.4	-	-0-	218.42	A3C
A3C	218.42	None	-	1.0	-	-0-	218.42	A4C
A4C			Rest of Route Not Shown					

SAMPLE CALCULATION OF PHYSICAL CIRCUIT FEEDER COST

SUPPLEMENTAL WORKSHEET - PHASE I

FIGURE 3h

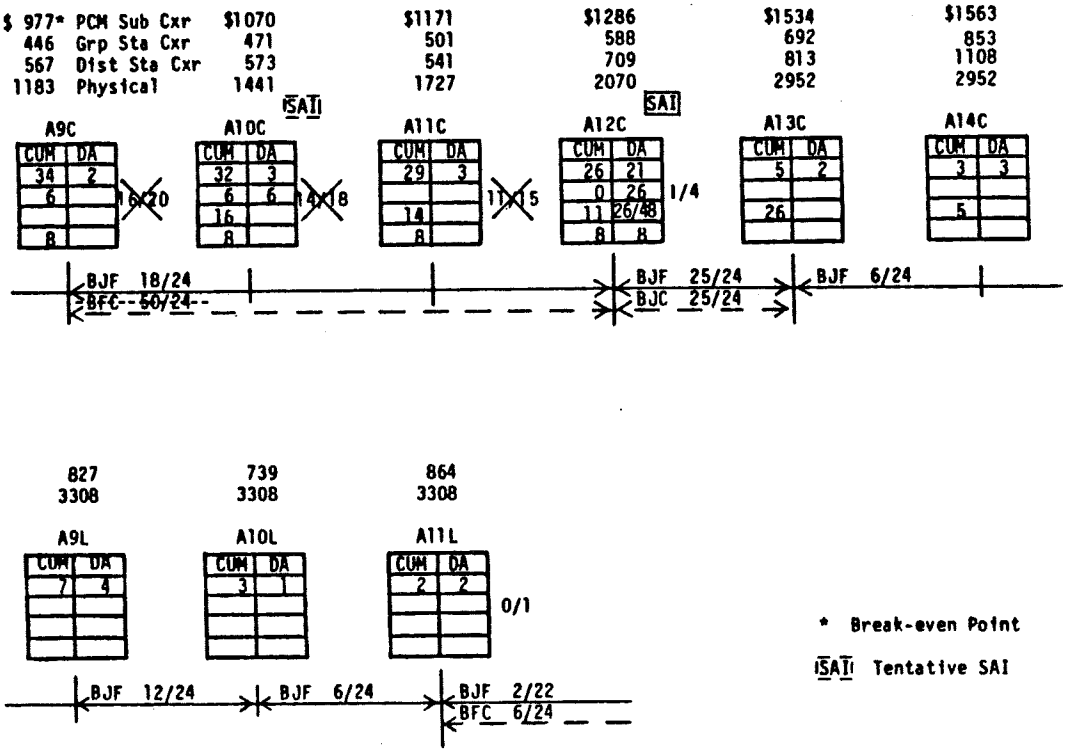
Location	Physical Feeder Circuit Cost	Pair Cost for Distributed and Grouped Sta. Cxr.	Adjusted Distributed Sta. Cxr. Cost	Distributed Sta. Cxr. Feeder Ckt. Cost	Adjusted Grouped Sta. Cxr. Cost	Grouped Sta. Cxr. Feeder Ckt. Cost	Pr. Cost PCM Sub. Cxr.	Adjusted PCM Sub. Cxr. Cost	PCM Sub. Cxr. Feeder Ckt. Cost
(a)	(b)	(c=bx1+8)	(d)	(e=c+d)	(f)	(g=c+f)	(h=bx6+24)	(i)	(j=h+i)
A0A	0	0							
A1A	218	27	563	590	441	468	55	645	700
A1.6A	218								
A2A	218	27	563	590	441	468	55	680	735
A2.6A	218								
A3A	218	27	544	571	423	450	55	696	751
A4A	515	64	538	602	416	480	129	725	854
A4.5A	722								
A5A	722	90	581	671	460	550	181	754	935
A5.8A	722								
A6A	722	90	575	665	454	544	181	783	964
A7A	722	90	569	659	448	538	181	811	992
A7.3A	831								
A8A	1201	150	425	575	304	454	300	653	953
A8.7A	1602								
A9A	1602	200	419	619	298	498	401	681	1082
A9.3A	1602								
A10A	1602	200	413	613	291	491	401	710	1111
A10.4A	1954								
A11A	2378	297	406	703	285	582	X	X	X
A11.7A	2378	297							
A12A	2378	297	450	747	329	626	X	X	X

SAMPLE CALCULATION OF CARRIER CIRCUIT FEEDER COST

SUPPLEMENTAL WORKSHEET - PHASE I

FIGURE 31

X: Cumulative subscriber total below 24.



EXAMPLE 1
PRELIMINARY PHASE II - SAVE WORKSHEET

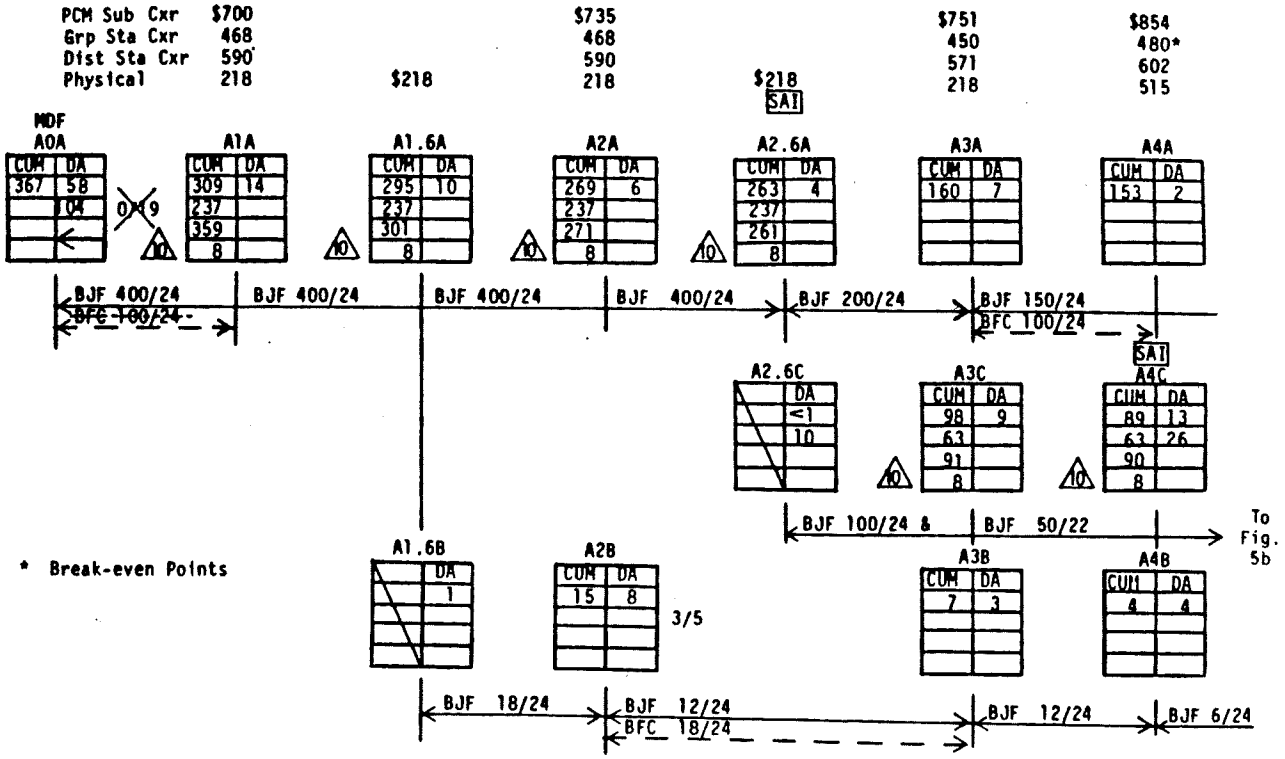
FIGURE 4a

DA Location	Dist. Pairs	Dist. Cxr. Chan.	Dist. Pairs for Cxr.	CUM	Cum. Phys. Feeders	Cxr. Pairs	Required Pairs	Fill Factor	Required Cable Pairs	Existing Cable Pairs	Cable Additions (Table 8)
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h=b+d+f+g)	(i)	(j=ixh)	(k)	(l)
A14C	3	0	0	END	0	0	3	1.11	4	6	NONE
A13C	3+2	0	0	A14C	0	0	5	1.11	6	6	NONE
A12C	5+21	0	0	A13C	0	0	26	1.11	29	25	BFC 25-24
	26										
At CUM Side of SAI					0	8					
A11C	3	0	0	A12C	0	8	11	1.11	13	18	NONE
A10C	3+3	0	0	A11C	0	8	14	1.11	16	18	NONE
	6					8					
At CUM Side of SAI					6	8					
A9C	2	0	0	A10C	6	8	16	1.11	18	18	NONE
Break-even point is at				A9C							

RECALCULATION OF CABLE ADDITIONS

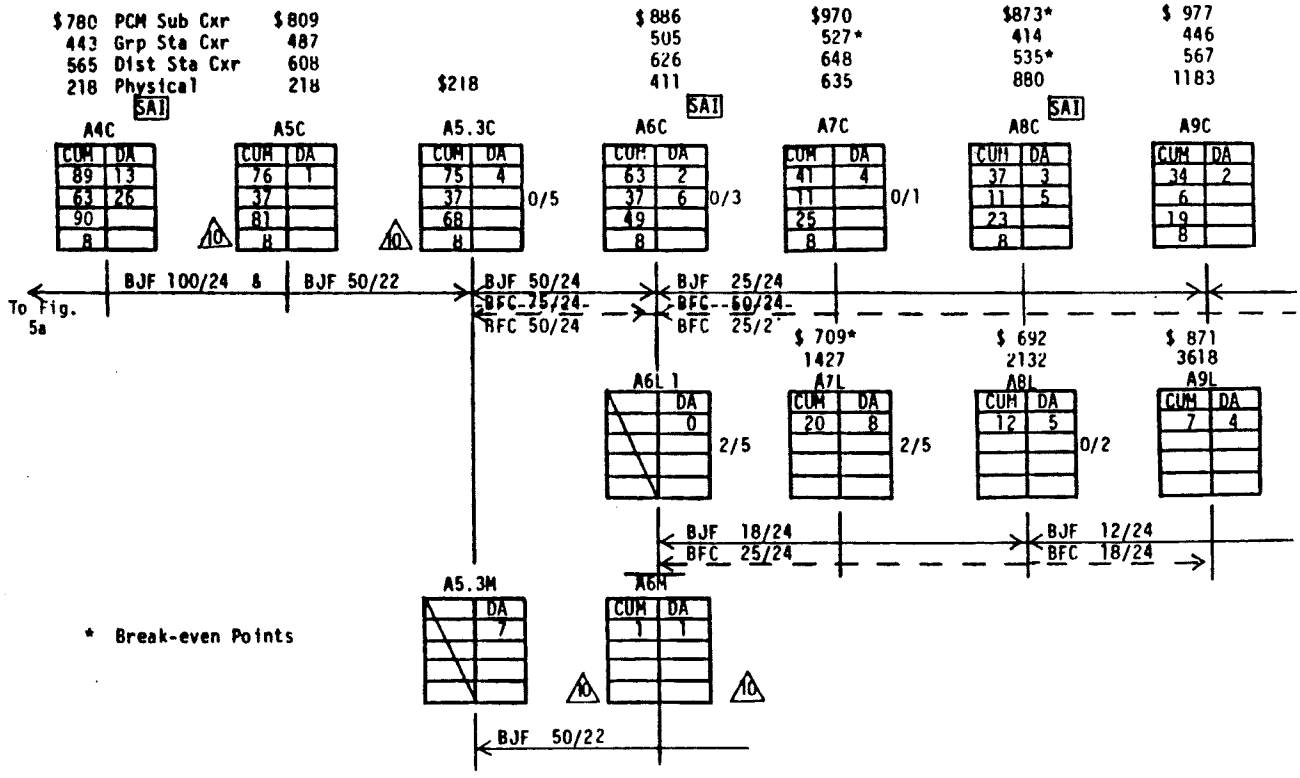
SUPPLEMENTAL WORKSHEET--PHASE II (Preliminary)

FIGURE 4b



EXAMPLE 1
PRELIMINARY PHASE III - SAVE WORKSHEET

FIGURE 5a



EXAMPLE 1
PRELIMINARY PHASE III - SAVE WORKSHEET

FIGURE 5b

DA Location	Dist. Pairs	CUM Location	CUM Physical Feeders	Cxr. Pairs	Trunk Pairs	Req'd Pairs	Req'd Pairs 90% Fill	Existing Cable Pairs	Cable Pair Shortage	Cable Reinforcement
(a)	(b)	(c)	(d)	(e)	(f)	(g)[1/]	(h=gx1.11)	(i)	(j=h-i)	(k)[2/]
A8C	2+3	A9C	6	8	0	19	22	25	0	NONE
	5		6	8	0					
At CUM Side of SAI			11	8	0					
A7C	4	A8C	11	8	0	23	26	25	1	BFC 25-24
A6C	4+2	A7C	11	8	0	25	28	25	3	BFC 25-24
A6L	8+0	A7L	12	0	0	20	23	18	5	BFC 25-24
	14		23	0	0					
At CUM Side of SAI			37	8	0					
A5.3C	4	A6C	37	8	0	49	55	50	5	BFC 50-24
A5.3M	1+7	A6M	0	0	10	18	20	50	0	NONE
	12		37	8	10					
A5C	12+1	A5.3CM	37	8	10	68	76	150	0	NONE
A4C	13+13	A5C	37	8	10	81	90	150	0	NONE
	26		37	8	10					
At CUM Side of SAI			63	8	10					
A3C	9	A4C	63	8	10	90	100	150	0	NONE
A1A	32+14	A1.6A	237	8	10	301	335	400	0	NONE
AOA	46+58	A1A	237	8	10	359	399	400	0	NONE
MDF	104		237	8	10					

RECALCULATION OF CABLE ADDITIONS

SUPPLEMENTAL WORKSHEET - PHASE III

[1/] g=b+d+e+f

[2/] Table 8

FIGURE 5c

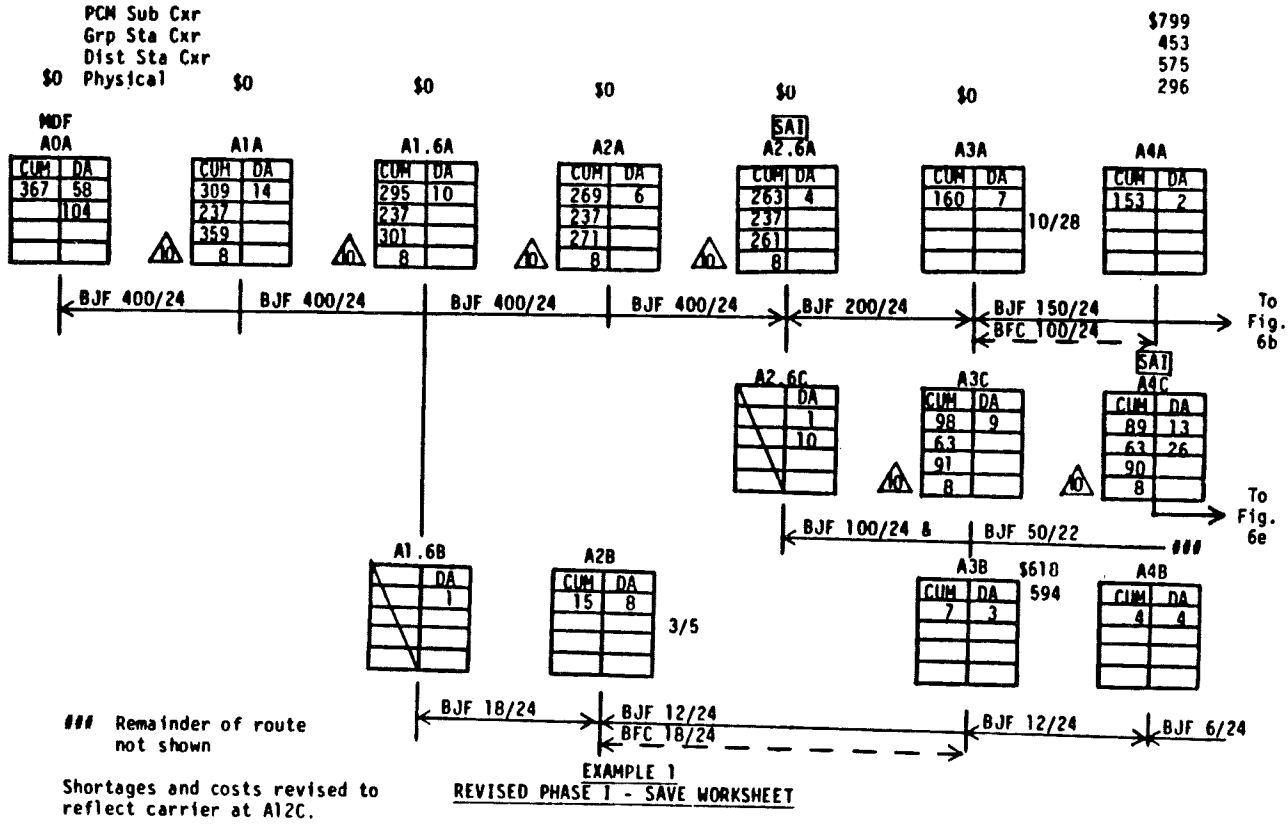


FIGURE 6a

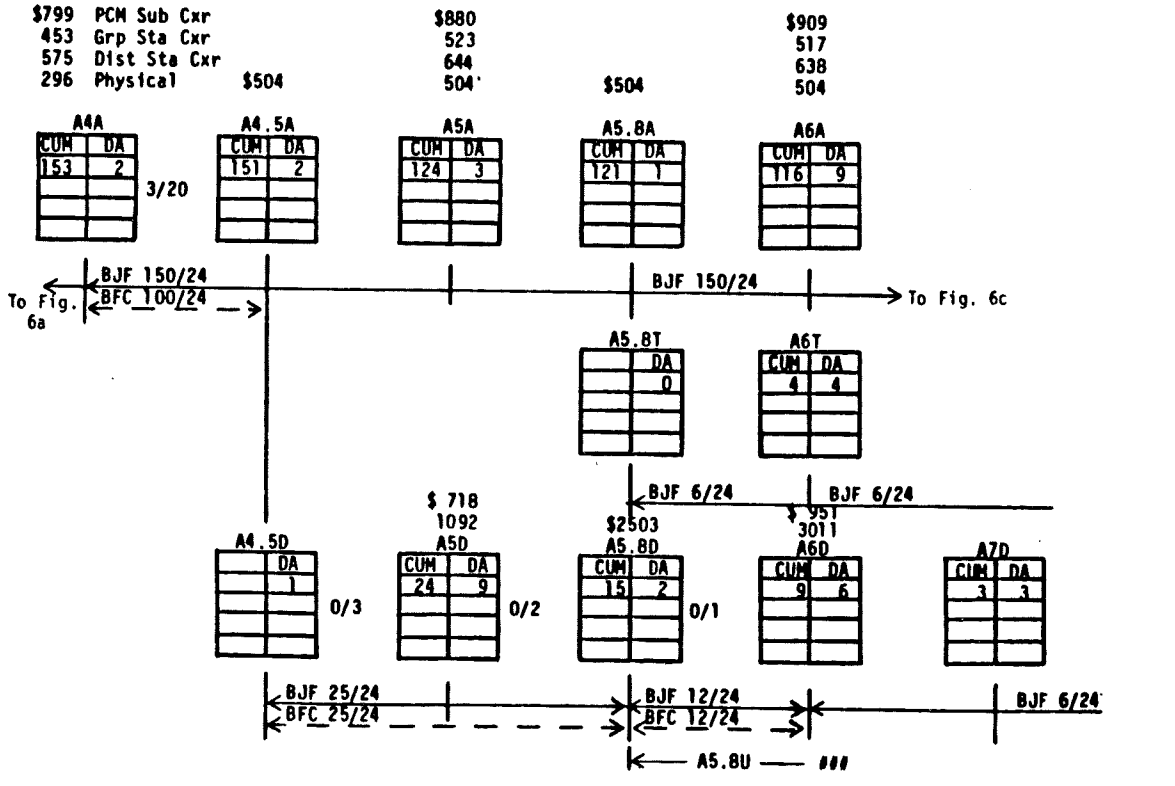
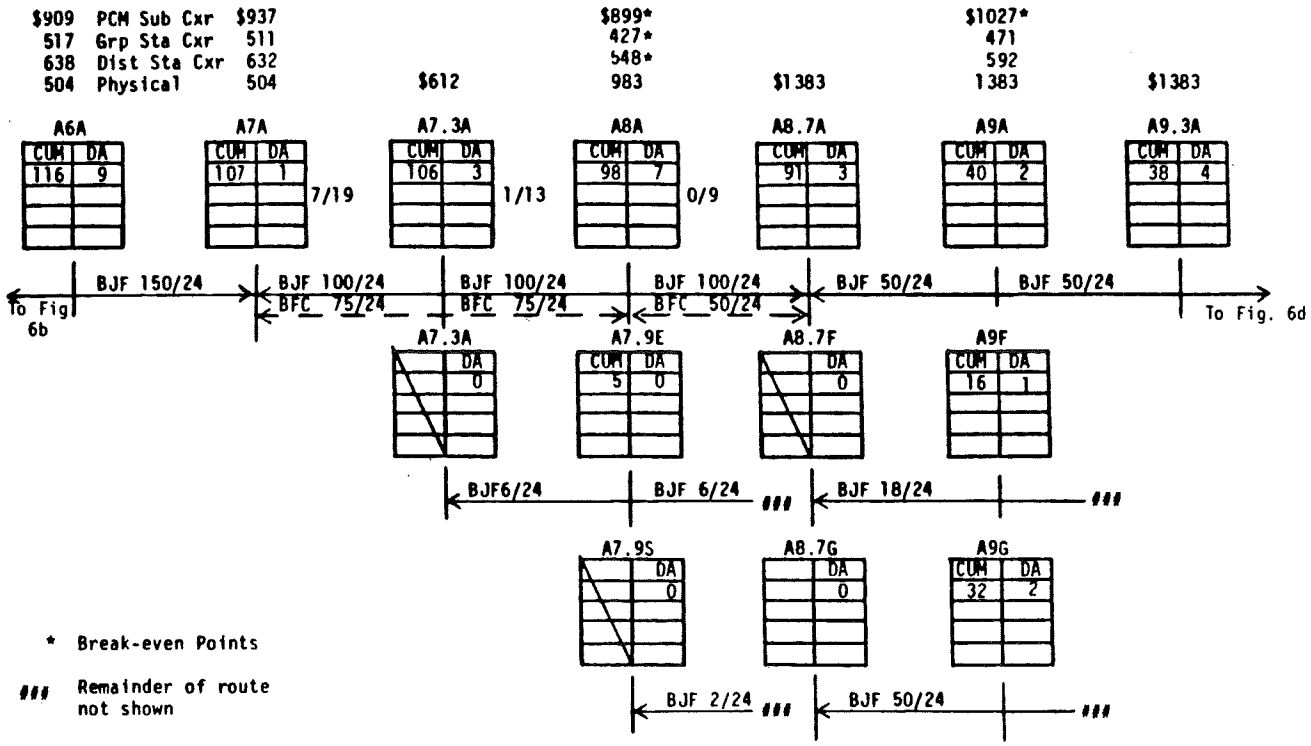
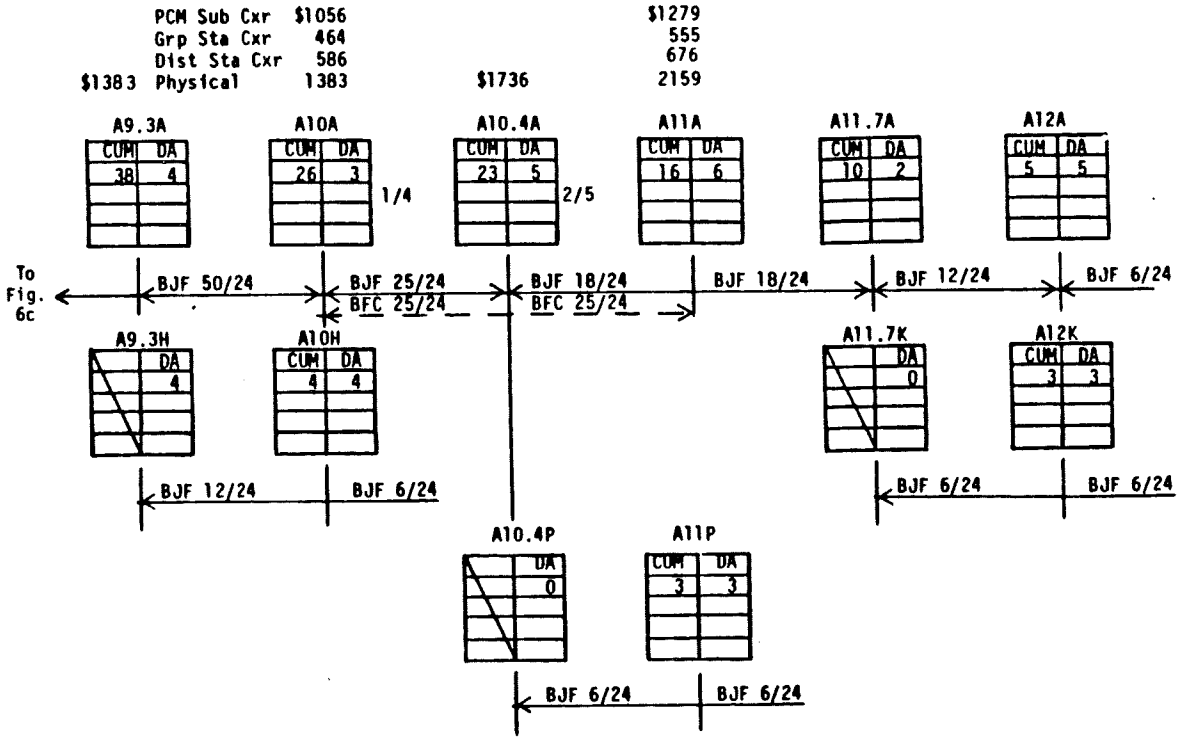


FIGURE 6b



EXAMPLE 1
REVISED PHASE I - SAVE WORKSHEET

FIGURE 6c



EXAMPLE 1
REVISED PHASE I - SAVE WORKSHEET

FIGURE 6d

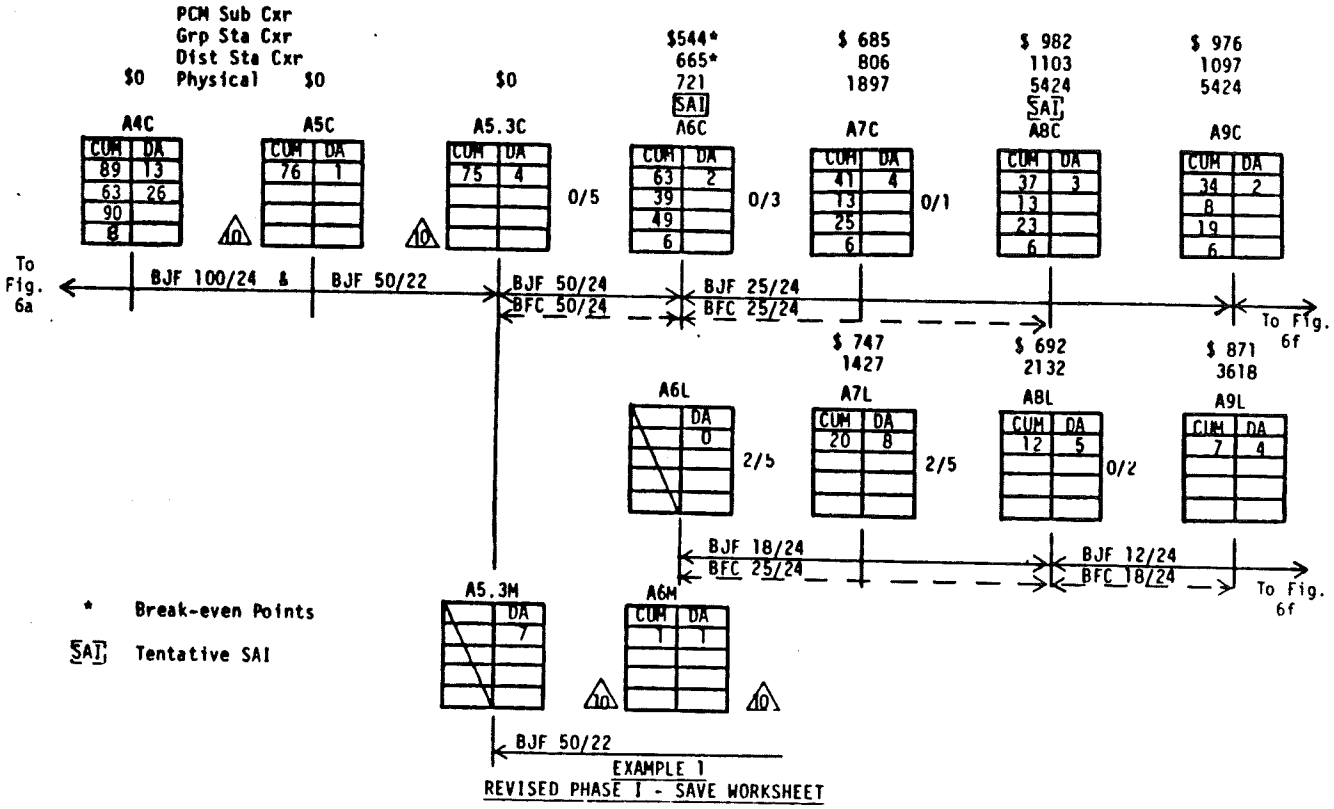
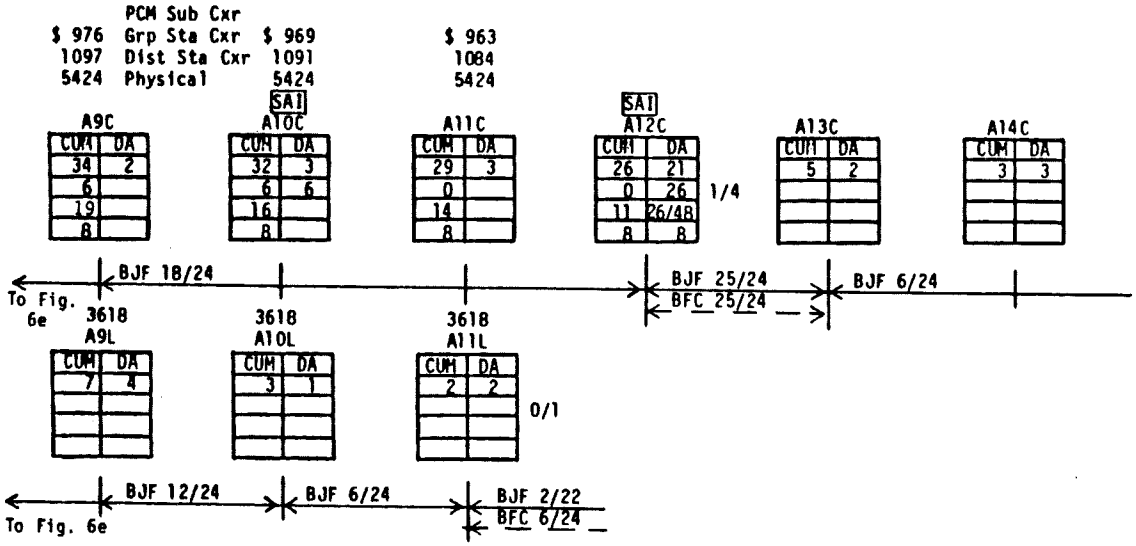
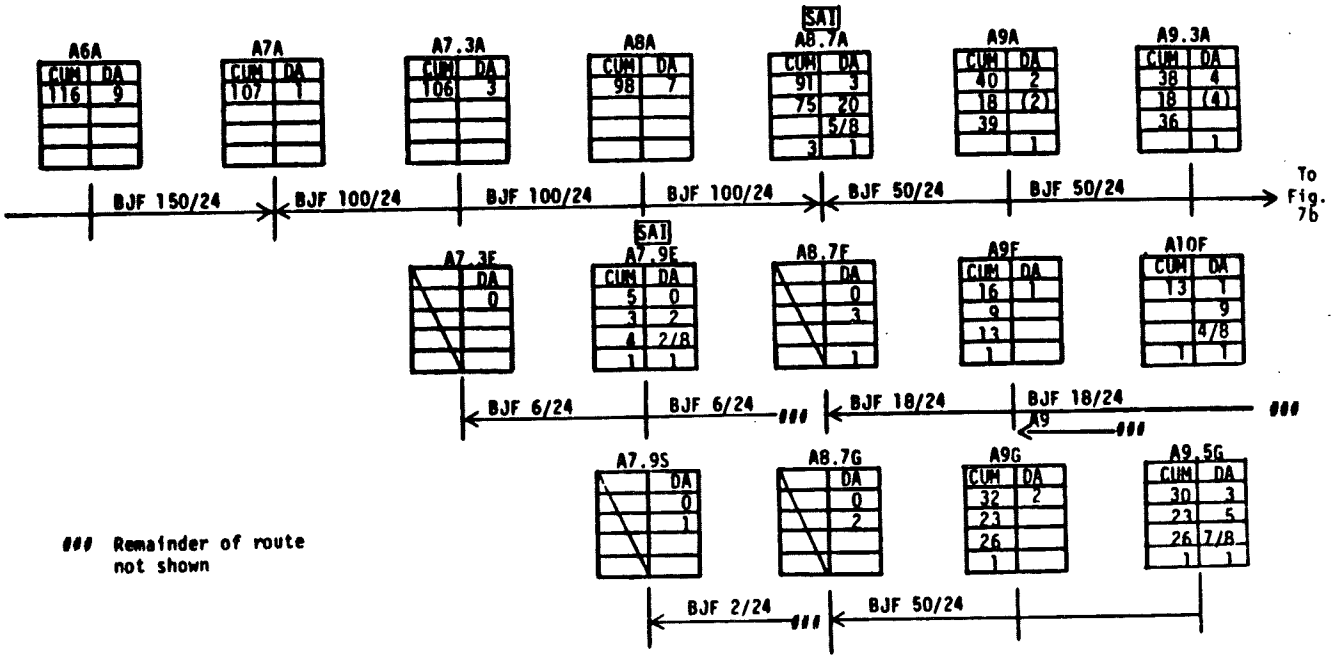


FIGURE 6e



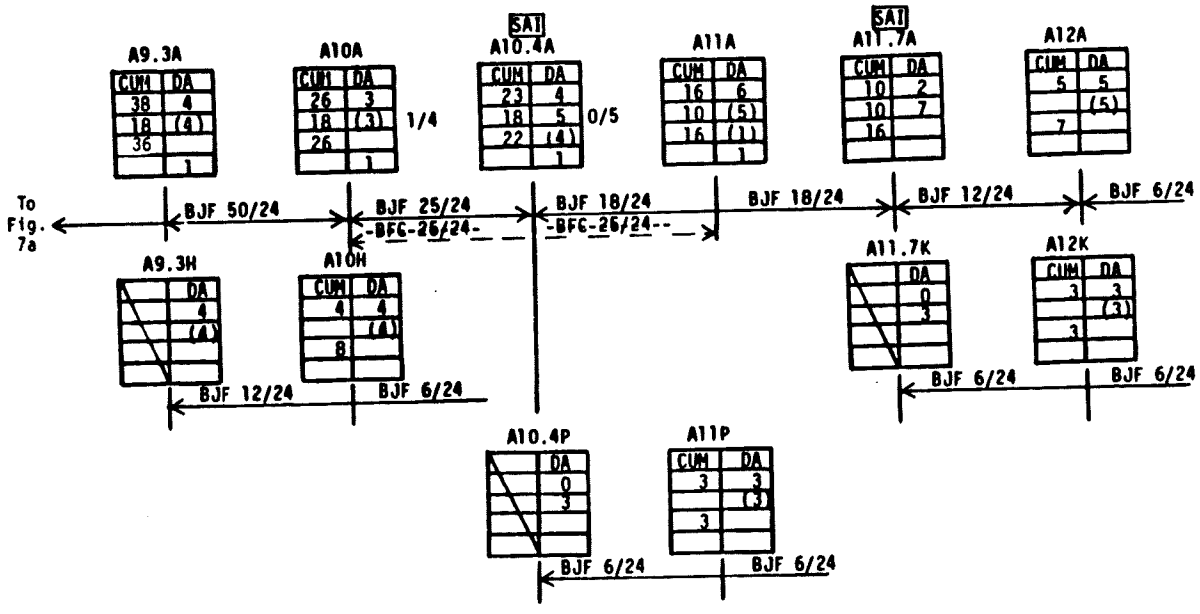
EXAMPLE 1
REVISED PHASE I - SAVE WORKSHEET

FIGURE 6f



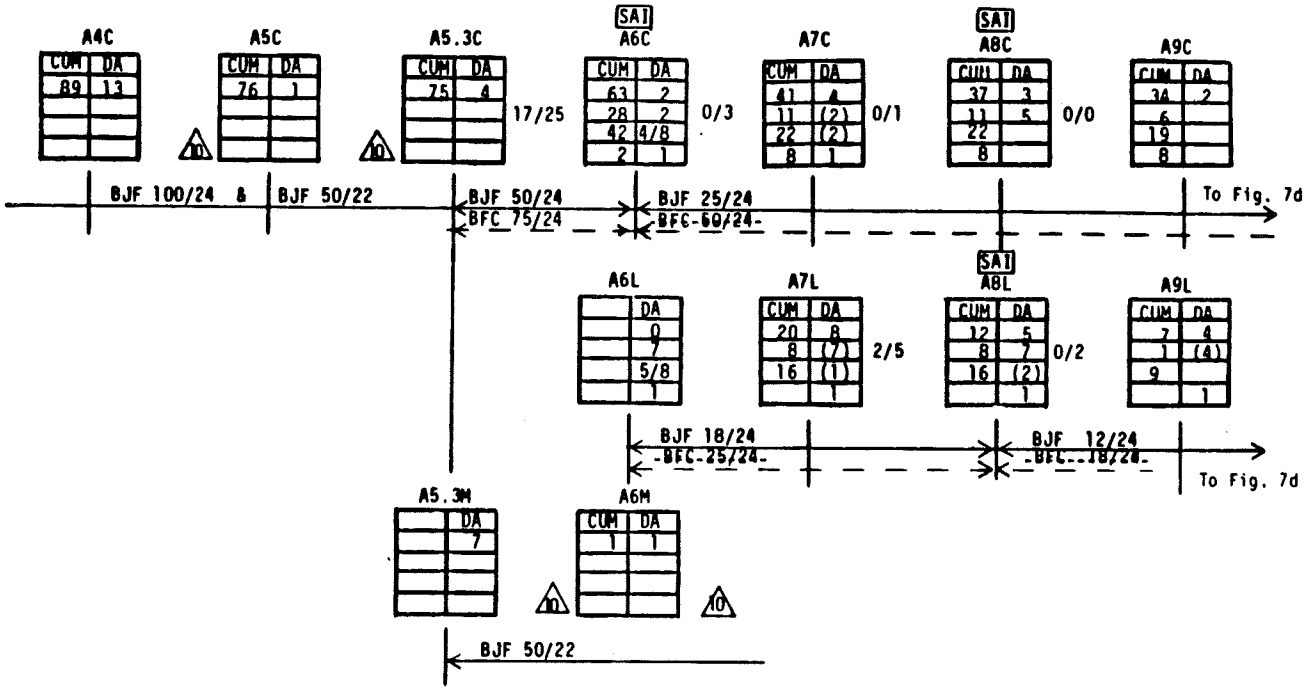
EXAMPLE 1
PHASE II - SAVE WORKSHEET

FIGURE 7a



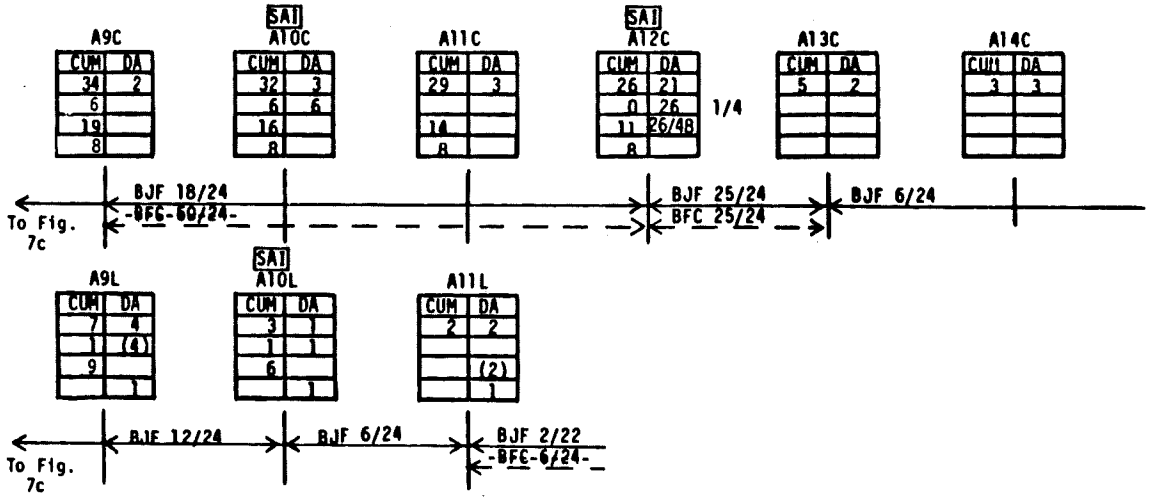
EXAMPLE 1
PHASE II - SAVE WORKSHEET

FIGURE 7b



EXAMPLE 1
PHASE II - SAVE WORKSHEET

FIGURE 7c



EXAMPLE 1
PHASE II - SAVE WORKSHEET

FIGURE 7d

Work Area Location	Existing Pairs	Max. 5-Yr. Fill	Pairs Avail.	Circuit Requirements: CUM Feeder Pr Phys	CUM Feeder Pr Cxr	Distribution Pairs: Preceding Sections Phys Pr	Preceding Sections Cxr	DA Sub	Pair Total Shortage 1/	DA Sub. on Physical	DA Sub. on Dist. Cxr
(a)	(b)	(c)	(d=bxc)	(e)	(f)	(g)	(h)	(i)	(j)	(k=e+j)	(l=-j)
A12A	6	90%	5	0	0	0	0	5	0	5	0
A11.7A*	12	90%	10	0	0	5	0	2	0	2	0
At SAI										7	
A12K	6	90%	5	0	0	0	0	3	0	3	0
A11.7K*	6	90%	5	0	0	3	0	0	0	0	0
At SAI										3	
A11A	18	90%	16	10	0	0	0	6	~~0~~ -1	~~0~~ 5	~~0~~ 1
A10.4A*	18	90%	16	10	0	5	1	4	~~0~~ -4	0	4
At SAI											
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
A9E	2			0	0	0	0	2			
A8E*	6			0	0	0	1	3			
At SAI											

* SAI

1/ j=d-(e+f+g+h+i plus 1 for each new distributed carrier in serving area)

SAMPLE CALCULATION OF DISTRIBUTED STATION CARRIER PLACEMENT

SUPPLEMENTAL WORKSHEET - PHASE II

FIGURE 7e

NOTE: (X)'s in columns j, k, and l do not indicate errors but changes made in the worksheets during the design process.

Work Area Location	Existing Pairs	Max. 5-Yr. Fill	Pairs Avail.	Circuit Requirements: CUM Feeder Pr Phys	CUM Feeder Pr Cxr	Distribution Pairs: Preceding Sections Phys Pr	Preceding Sections Cxr	DA Sub	Pair Total Shortage 1/	DA Sub. on Physical	DA Sub. on Dist. Cxr
(a)	(b)	(c)	(d=bxc)	(e)	(f)	(g)	(h)	(i)	(j)	(l=e+j)	(l=-j)
A9C	18	90%	16	6	8	0	0	2	0	2	0
A8C	25	90%	22	6	8	2	0	3	0	3	0
At SAI										5	
A7C	25	90%	22	11	8	0	0	4	-2	2	2
A6C	25	90%	22	11	8	2	1	2	-2	0	2
At SAI										2	4
A11L	2	90%	1	0	0	0	0	2	-2	0	2
A10L	6	90%	5	0	0	0	1	1	0	1	0
At SAI										1	2
A9L	12	90%	10	1	0	0	1	4	0	4	0
A8L	12	90%	10	1	0	4	1	5	-1	4	1
At SAI										8	1
A7L	18	90%	16	9	0	0	1	8	-2	6	2
A6L	18	90%	16	9	0	6	1	0	0	0	0
At SAI										6	

1/ j=d=(e+f+g+h+i plus 1 if new distributed carrier in serving area)

SAMPLE CALCULATION OF DISTRIBUTED STATION CARRIER PLACEMENT

SUPPLEMENTAL WORKSHEET - PHASE II

FIGURE 7f

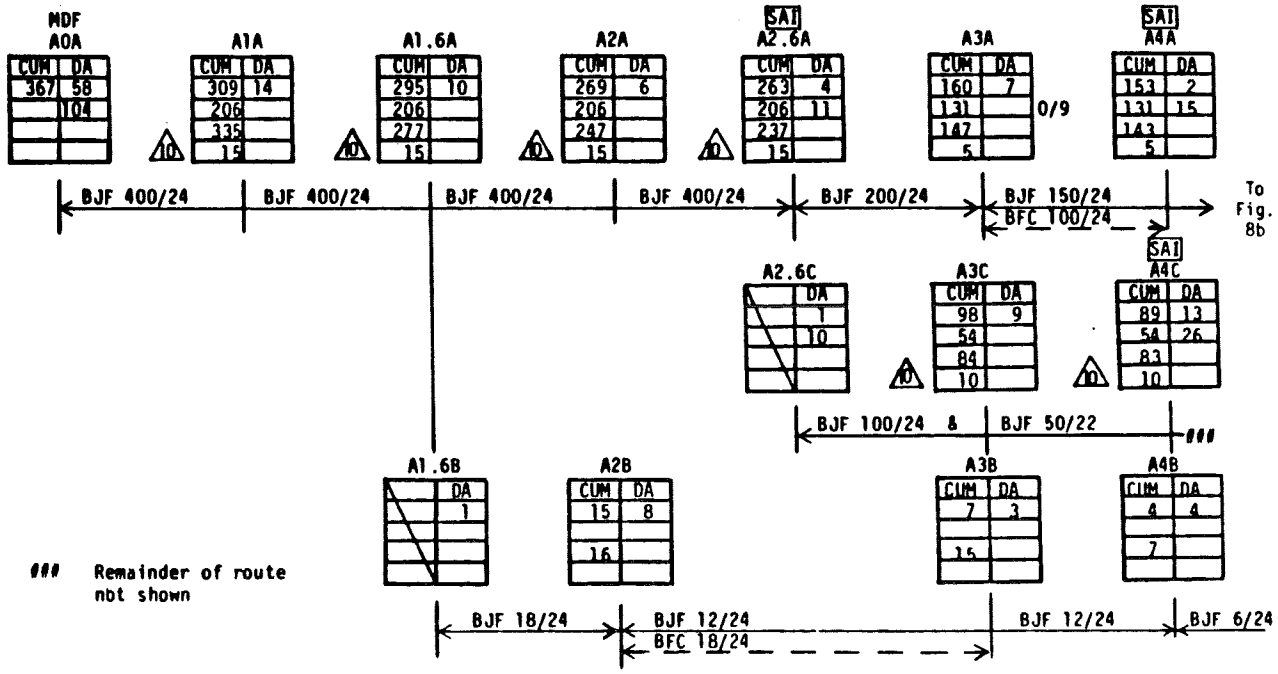
DA Location	Dist. Pairs	Dist. Cxr. Chan.	Dist. Pairs for Cxr.	CUM	Cum. Phys. Feeders	Cxr. Pairs	Required Pairs	Fill Factor	Required Cable Pairs	Existing Cable Pairs	Cable Additions Pairs
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h=b+d+f+g)	(i)	(j+ixh)	(k)	(l)
A12A	5	0	0	END	0	0	5	1.11	6	6	NONE
A11.7A*	7	0	0	A12A	0	0	7	1.11	8	12	NONE
A12K	3	0	0	END	0	0	3	1.11	4	6	NONE
A11.7K*	3	0	0	A12K	0	0	3	1.11	4	6	NONE
A11A	5	1	1	A11.7A	10	0	16	1.11	18	18	NONE
A10.4A*	5	4	1	A11A	10	0	16	1.11	18	18	NONE
A11P	3	0	0	END	0	0	3	1.11	4	6	NONE
A10.4P*	3	0	0	A11P	0	0	3	1.11	4	6	NONE
A10A	3	0	1	END	18	0	22	1.11	25	25	NONE
A9.3A*	7	0	1	A9E	18	0	26	1.11	29	50	NONE

* SAI

RECALCULATION OF CABLE ADDITIONS

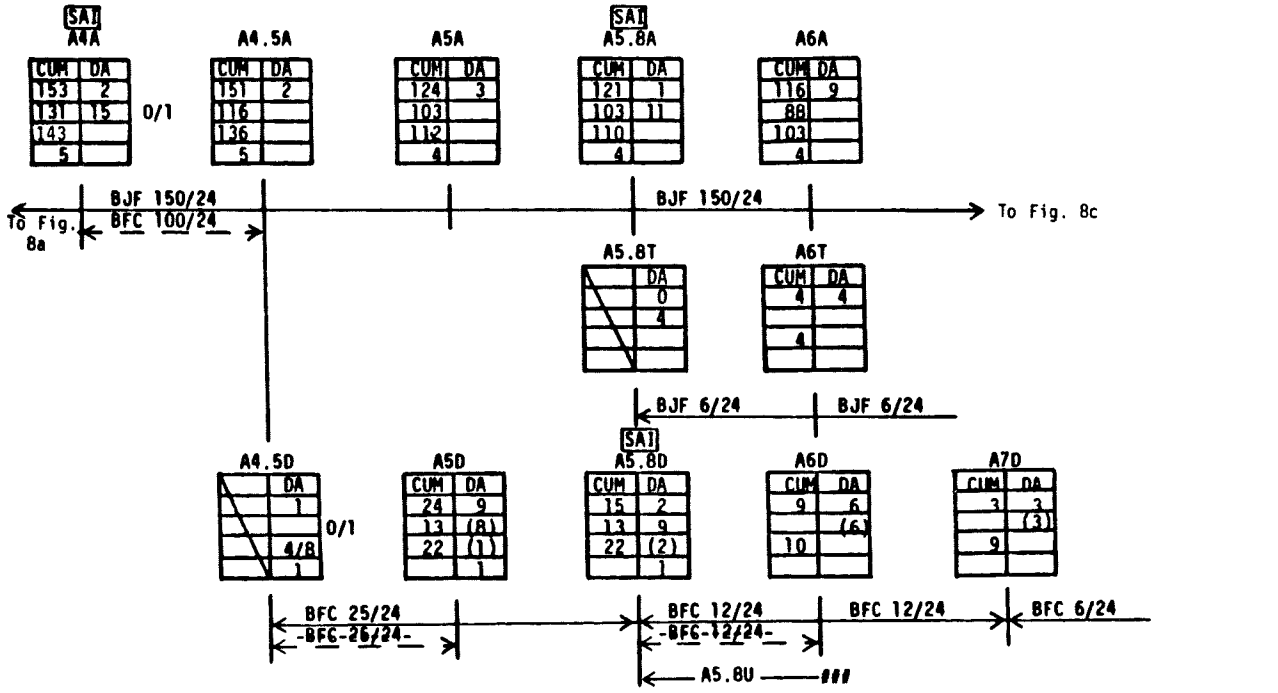
SUPPLEMENTAL WORKSHEET - PHASE II

FIGURE 7g



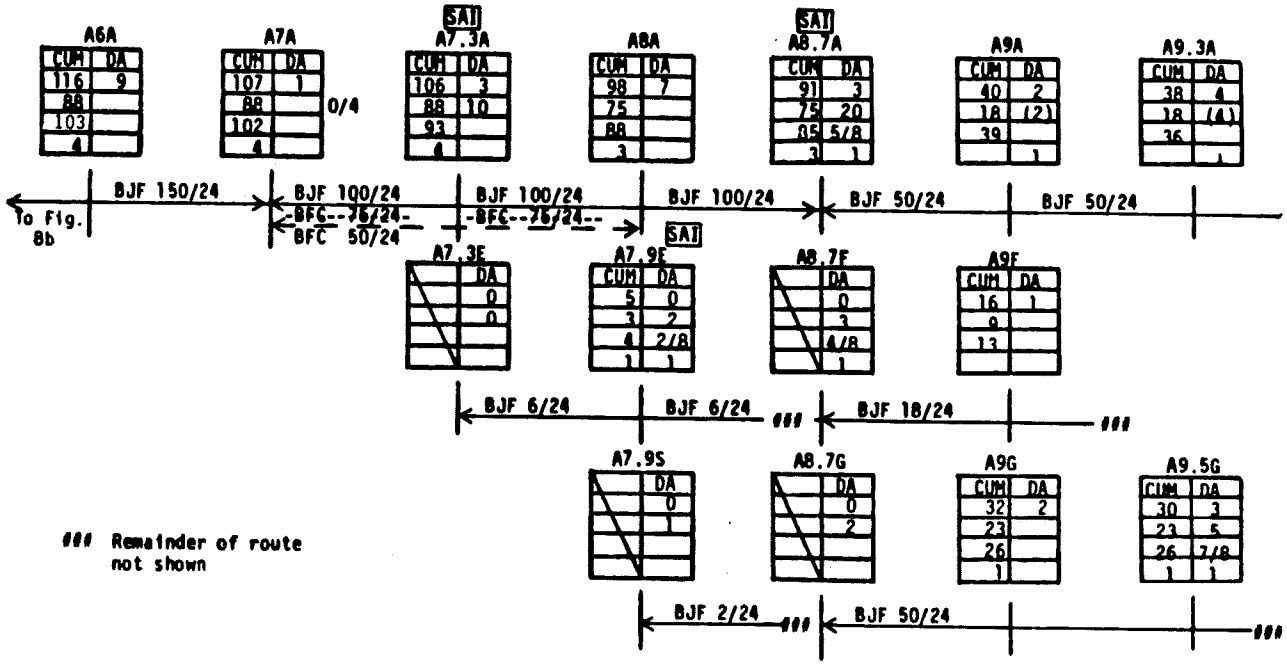
EXAMPLE 1
PHASE III - SAVE WORKSHEET

FIGURE 8a



EXAMPLE 1
PHASE III - SAVE WORKSHEET

FIGURE 8b



Remainder of route not shown

EXAMPLE 1
PHASE III - SAVE WORKSHEET

FIGURE 8c

DA Location	Dist. Pairs	CUM Location	CUM Physical Feeders	Cxr. Pairs	Trunk Pairs	Req'd Pairs	Req'd Pairs 90% Fill	Existing Cable Pairs	Cable Pair Shortage	Cable Reinforcement
(a)	(b)	(c)	(d)	(e)	(f)	(g)[1]	(h=gx1.11)	(i)	(j=h-i)	(k)[2]
A8A	7	A8.7A	75	3	0	85	95	100	0	NONE
A7.3A	7+3	A8A	75	3	0	88	98	100	0	NONE
A7.3E	0	A7.9E	3	1	0	4	5	6	0	NONE
	10		78	4	0					
A7.3A CUM Side of SAI			88	4	0					
A7A	1	A7.3A	88	4	0	93	104	100	4	BFC 50-24
A6A	1+9	A7A	88	4	0	102	114	150	0	NONE
A5.8A	1+10	A6A	88	4	0	103	115			
A6T	4	END	0	0	0	4	5	6	0	NONE
A5.8T	4	A61	0	0	0	4	5	6	0	NONE
	15									
A5.8A CUM Side of SAI			104	40						
A1A	32+14	A1.68	208	13	10	277	308	400	0	NONE
A0A	46+58	A1A	208	13	10	335	372	400	0	NONE
MDF	104									

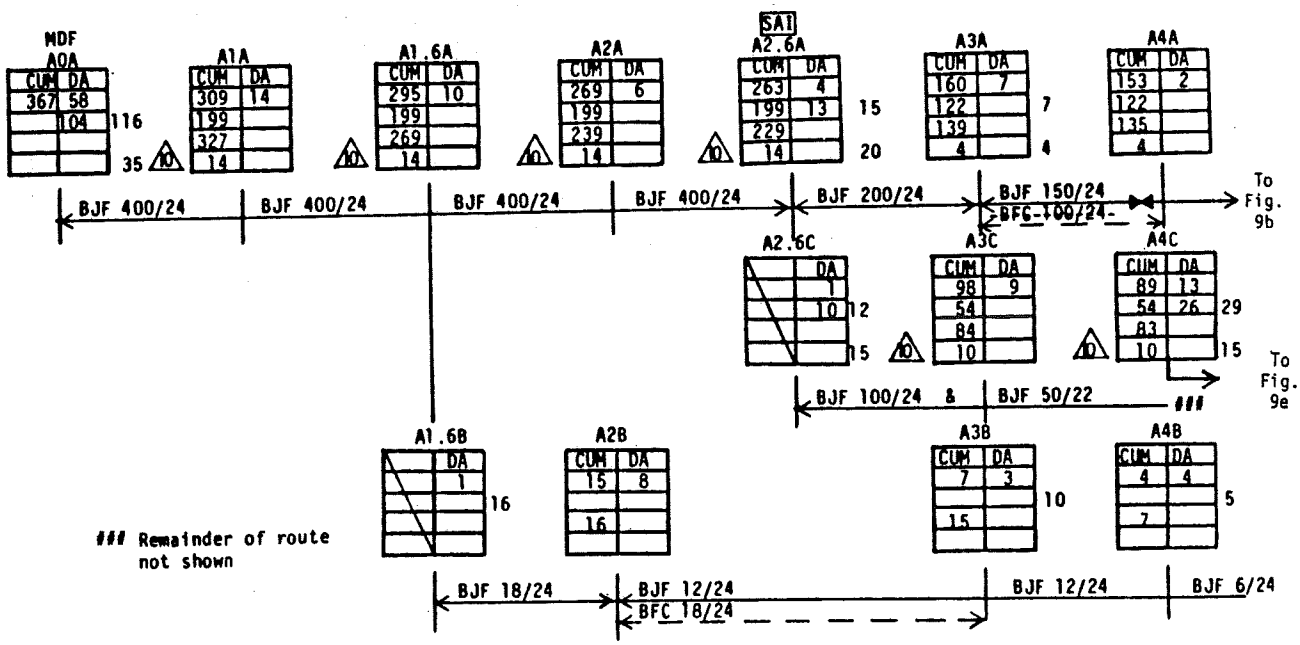
RECALCULATION OF CABLE ADDITIONS

SUPPLEMENTAL WORKSHEET - PHASE III

FIGURE 8d

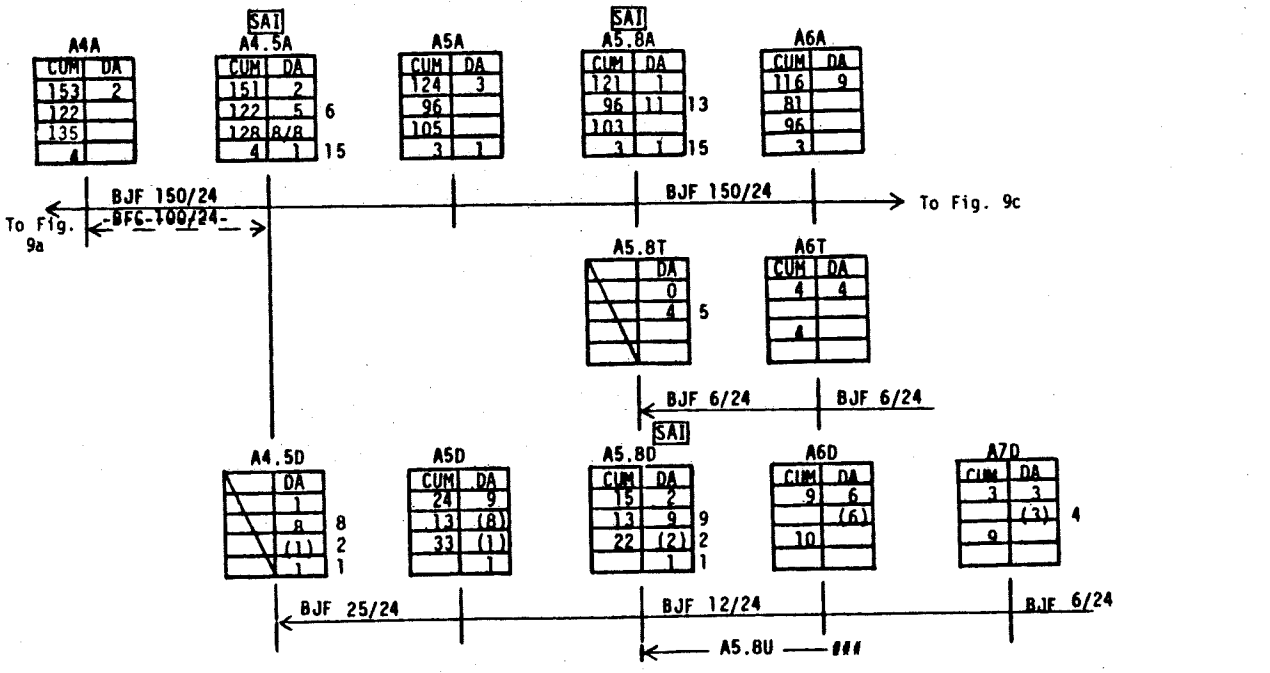
1/ 2=b+d+e+f

2/ Table 8



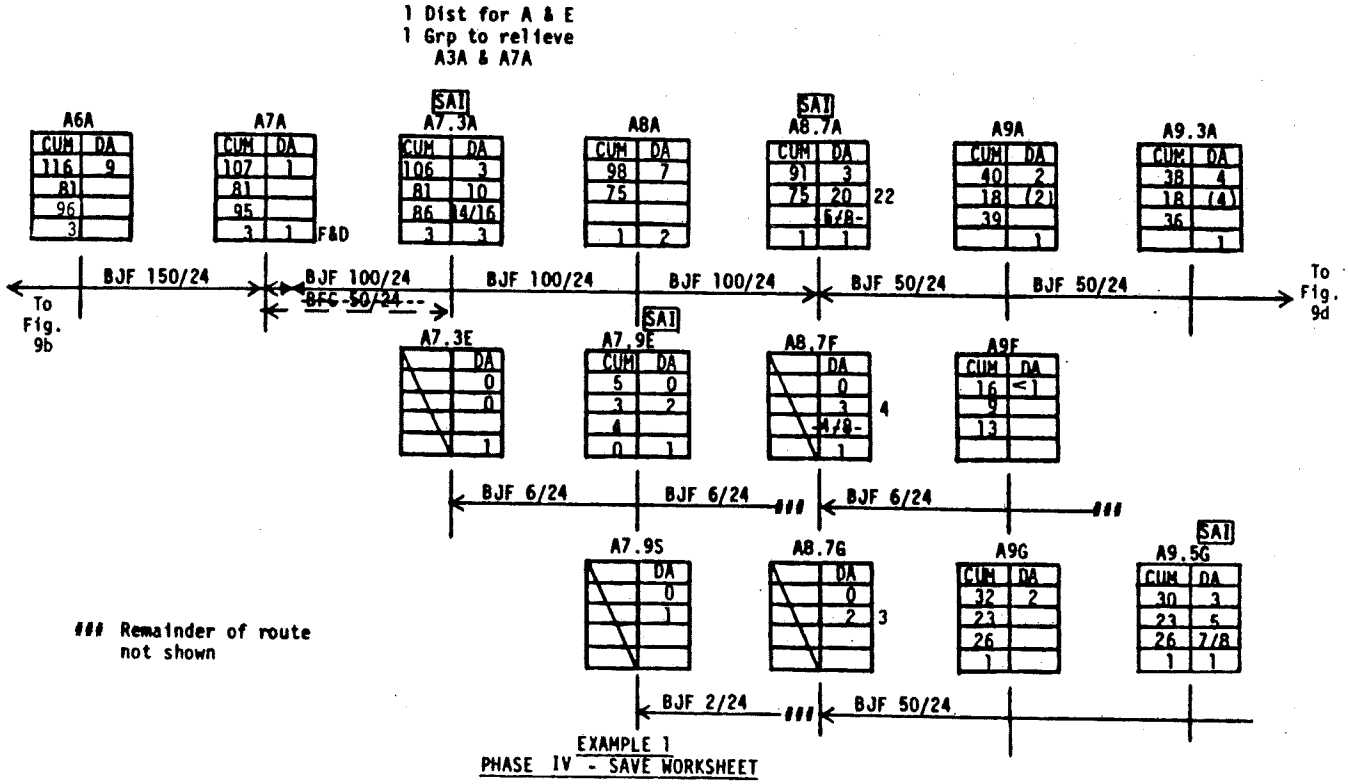
EXAMPLE 1
PHASE IV - SAVE WORKSHEET

FIGURE 9a



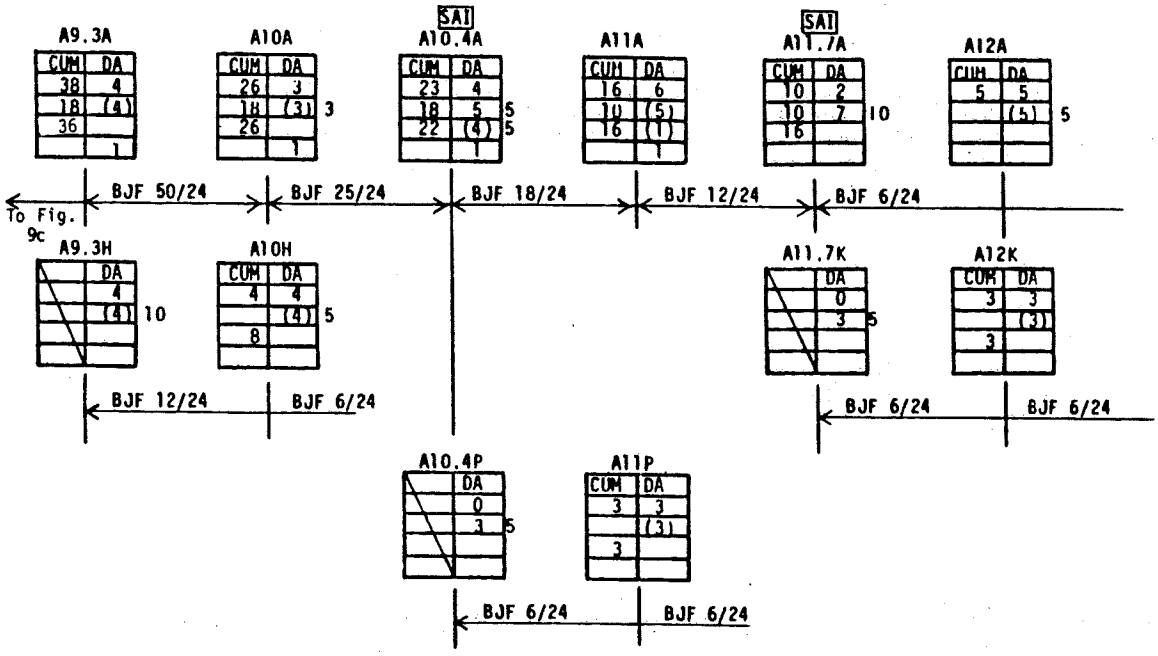
EXAMPLE 1
PHASE IV - SAVE WORKSHEET

FIGURE 9b



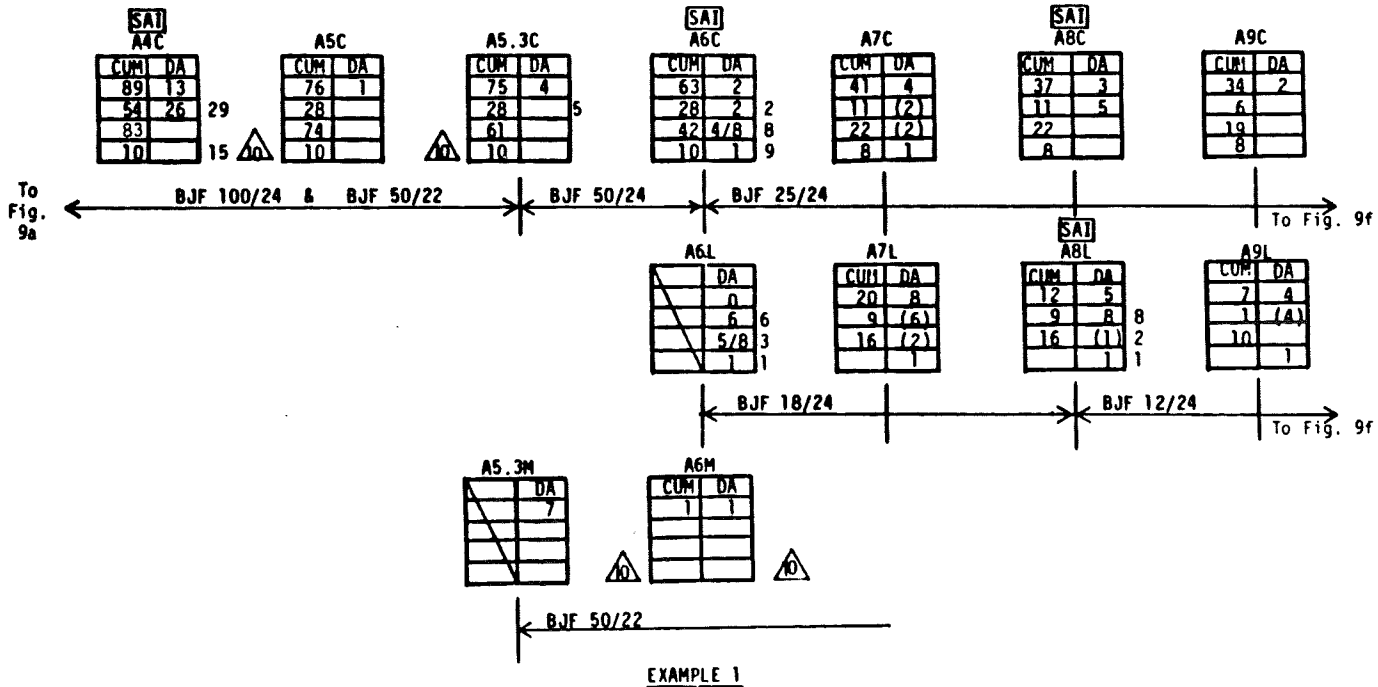
EXAMPLE 1
PHASE IV - SAVE WORKSHEET

FIGURE 9c



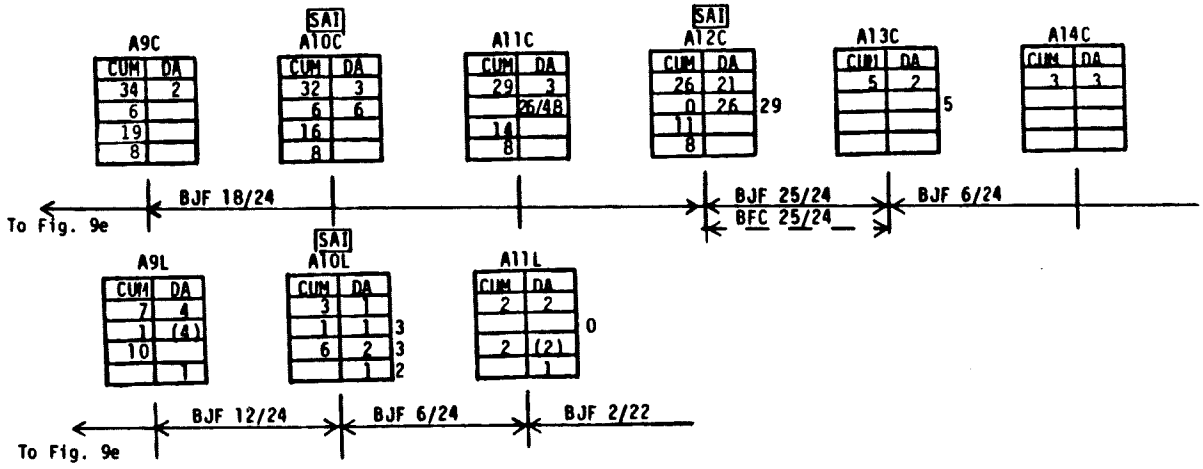
EXAMPLE 1
PHASE IV - SAVE WORKSHEET

FIGURE 9d



EXAMPLE 1
PHASE IV - SAVE WORKSHEET

FIGURE 9e



EXAMPLE 1
PHASE IV - SAVE WORKSHEET

FIGURE 9f

APPENDIX 2

NEW CONSTRUCTION OR TOTAL REPLACEMENT OF PLANT (EXAMPLE 2)

This example presents a detailed step-by-step illustration of the four phases of a SAVE design for the situation where either an all new construction of a cable route or the total replacement of existing cable on an existing route is required.

PHASE I: Initial Physical Requirement, refer to Figures 10a thru 10d. Prepare SAVE worksheets. In the case of a new cable route, it is possible that loading may not be required due to the use of carrier based pair gain devices. When station carrier is used, its short loop limits would preclude the use of load coils. In the case of RST's, these units have the same voice limits as a central office, 8.0 dB. Loading is not required on loops less than 18 kf in length. However, in most cases plant is not being installed to serve new areas. Instead it is replacing or reinforcing unmaintainable cable that cannot support carrier span lines. Since there is existing cable with existing loading, the new plant will have to be tied to the existing plant. Therefore, the load coil locations should be shown since they do (or will) exist and will affect the cable design. They are also useful access points.

Calculate pair sizes. The zero column of Table 8 or the fill factors of Table 9 can be used as they are the same.

Cable size between A8A and A8.7A: Requirements = 91 from CUM at A8.7A and 7 from DA at A8A = 98 X factor of 1.11 = 109 needed including spares. Place 150 pair cable. A8.7F to A9F: (16 + 0) X 1.79 = 29. Place 50 pair cable. A8.7A to A9A: 40 from CUM at A9A + 3 from DA at A8.7A; 43 X 1.42 = 62. Place 75 pair cable.

Calculate feeder circuit costs. Use average incremental cost per pair - section ($67 per 24 gauge pair - section). Study a number of different pair-gain equipment types and configurations to determine the best equipment type.

Cost of physical circuit at A7.3A = $436 at A7A + .3 X $67 = $456. At A8A = $456 + .7 X $67 = $503. At A7.9E = $456 + .6 X $67 = $496.

Cost of distributed station carrier circuits at A8A = $425 (Table 2) + $\frac{503}{8}$ = $488.

Cost of grouped station carrier circuits at A8A = $304 (Table 2) + $\frac{503}{8}$ = $367.

Cost of single 96 channel PCM subscriber carrier terminal circuits at A8A = $383 (Table 4) + $\frac{503}{8}$ = $446.

Cost of four 24 channel PCM carrier terminal (on same route) circuits at A8A = $495 (Table 3) + $\frac{\$503}{8}$ = $558.

Cost of RST derived circuit at A8A using broad gauge costs = $284 (64 lines, Table 5) + $\frac{\$503}{10.7}$ = $331.

Since the number of terminal line sizes given in Table 5 is limited and RST's have a very expensive common equipment component in comparison to line costs, distortion can result in the RST feeder circuit costs. An approach is to initially use broadgauge costs to find possible locations and then 'zero in' by computing costs for individual locations. On the SAVE worksheets individual costs for each A route design area are listed above the broadgauge costs.

Cost of RST derived circuit at A8A using Appendix of TE&CM 232

= (($25,000 base cost - 98 lines)

+ $150 lines cost = $150 CO line credit

+ ($667 per RST location X 7 loc. - 98 lines)

- 190 VF treatment) X 1.25

+ ($503 per pr X 6 pairs - 98 lines)

= $172 per circuit

PHASE II: Design beyond break-even point, analysis and selection of pair gain equipment.

Analyze carrier feeder circuit costs and permanent break-even points (PBE), refer to Figures 10a-d.

Grouped station carrier's PBE is at A6A. Beyond A6A it should be less expensive to use carrier derived feeder circuits instead of physical cable pairs. Distributed station carrier's PBE is at A7A. The cost differential between two types at A7A is $121. The $121 is nearly equal to $134, the average cost of the longest possible distribution pair is a 'standard (9 kf - D-66) load coil bounded serving area. The dc ohm drop limits of grouped station carriers will probably preclude the use of the standard (9 kf deep) serving area. Furthermore, since load coils do not exist yet, cable branch points will be used for SAI locations. These factors will reduce the distribution plant cost. They may also reduce the serving areas to the point that there are less than the 16 subscribers per serving area upon which the grouped station carrier costs were based. However, the common equipment costs of grouped station carrier are not very high and grouped carrier fits in better with the SAVE concepts of dedicated distribution plant and nondedicated feeder plant.

PCM subscriber carrier used in the multiterminal configuration does not have a break-even point on the A route. If the demographic conditions had been different, such as longer cable routes and clusters of subscribers, the multiterminal configuration might have had a break-even point.

The single terminal PCM carrier system does have a break-even point at A7A. Its use becomes uneconomical at and beyond A9A due to the sharp reduction in the cumulative subscriber quantity at A8.7A. Inside of the A8.7A the circuit costs are based upon a 96 channel terminal (four 24-channel systems grouped together). Beyond A8.7A circuit costs are based on a 24-channel terminal. In addition the circuits costs are the same as distributed station carrier. Even if the circuit costs were less than grouped station carrier, feeder cable pairs (more than the 9 kf allotted for distributed plant) would be required to connect the subscribers to the carrier terminals. To make a fair comparison the cost of feeder cable pairs (on the PCM's drop side) and voice frequency treatment (if required) would have to be added to the cost of the PCM carrier equipment.

Using broadgauge costs (Table 5), the break-even point for an RST is at A8A. The circuit costs are slightly less than the circuit costs for grouped station carrier. As with PCM carrier feeder circuit costs (drop side) would have to be added to the RST line circuit cost. However, the RST circuit cost is based upon a 64 line unit at A8A. The cost per line for 98 lines would be a lot lower.

Using costs that reflect the CUM Subscriber Quantity at the individual load points, the RST's have a break-even point at A4A. Beyond A9A they are no longer economical. Since the RST circuit costs do not include that of drop side feeder pair and VF treatment, they cannot be used to ascertain if a RST based design is less expensive than the station carrier design. They also do not indicate the most economical RST design. To evaluate the RST design first prepare a SAVE design for the best alternative. In this case it is the grouped station carrier design and not the physical feeder circuit design of Phase I.

Prepare Phase II and Phase III station carrier design at least beyond the RST break-even point.

PHASE II: Grouped station carrier design beyond break-even point. Refer to Example 2a, Figure 11a. Locate grouped station carrier terminals at the break-even point, A8A and at the cable branch points beyond A8.7A, A9.3A, etc. Show equipped carrier channels over wired capacity for each serving area in the DA block at the SAI as well as the carrier pairs in the DA and CUM blocks. Show the required pairs for each work (design) area in the CUM blocks. Recalculate cable. For example A11A to A11.7A = 6 from DA at A11A (physical distribution pairs) plus 2 Cxr (feeder pairs) = 8 required pairs.
8 X 1.9 fill factor = 15.2. Provide 18 pair cable, cross out 50 pair cable.

PHASE III: Design inside break-even point of grouped station carrier, Example 2a, Figures 12a-c. Place SAI's at the cable branch points beyond A4A (to control loaded loops) and at A2.6A, a major route junction. There are actually too many SAI's A5.8A, A7.3A, A8A, and A8.7A. In Phase IV some of these would be combined. Compute and show required pairs. Required pairs for design area A7A = 4 physical feeder + 15 carrier feeder + 1 distribution = 20. Place 20 in A7.3A CUM block. Recompute cable. 20 X 1.79 = 36. Show 50 pair. Cross out 150 pair.

Compare RST based SAVE design to alternative designs.

Use the feeder circuit costs that were developed in Phase I. Beginning at A4A, the first RST break-even point, and ending at A8.7A, a summary of the feeder circuit costs will be prepared for each RST design alternative. A comparison station carrier based design will be made for each RST alternative. Inside of the RST location, it is assumed that physical feeder circuit costs are the same. To make a fair comparison, physical circuit costs will be added to the station carrier design for circuits in the area between the RST location (for example A4A) and the first station carrier terminal (A8A). For station carrier terminals/SAI that are not located at load coil (LC) points, the feeder circuits for the next LC point will be used. The cost of the (drop side) feeder cable circuits and voice frequency treatment will be added to the cost of the RST lines serving any SAI beyond the RST's immediate serving area. The serving areas for the RST design are assumed to be the same as the station carrier's.

Grouped Station Carrier (GSC) Design versus RST at A4A.

GROUPED STATION CARRIER FEEDER CIRCUIT COSTS

SAI Location	Circuit Quantity	Cost per Circuit	Extended Cost
A11.7A & K	10	$425	$4,250
A10.4A & P	13	373	4,849
A9.3A & H	15	371	5,565
A8.7A, F & G	7	369	2,583
A8A	7	367	2,569
A11F	12	373	4,476
A9F & V	4	369	1,476
A11.5G & N	16	425	6,800
A9.5G & J	7	371	2,597
A9.7 J & Q	7	371	2,597
A8.3E & R	4	369	1,476
	102		$39,238

SAI Location	Circuit Quantity	Cost per Circuit	Extended Cost
A7.3A & E	4	$456	$1,824
A5.8A & T	15	355	5,325
A4.5A & D	15	268	4,020
A4A	2	235	470
A5.8D & U	15	355	5,325
	51		$16,964
Total Ckts:	153		
LE/VFR	1	187.5	188
TOTAL STATION CARRIER DESIGN @ A4A			$56,390

RST Feeder Circuit Cost

RST Cost:			
A4A	153	$229	$35,037

Feeder Circuit Cost Beyond RST

A11.7A & K	10	$750	$7,500
A10.4A & P	13	663	8,619
A9.3A & H	15	590	8,850
A8.7A, F & G	7	549	3,843
A8A	7	503	3,521
A7.3A & E	4	456	1,824
A5.8A & T	15	355	5,325
A4.5 & D	15	268	4,020
A4A	2	235	470
A11F	12	704	8,448
A9F	4	570	2,280
A11.5G & N	16	737	11,792
A9.5G & J	7	603	4,221
A9.7 J& Q	7	623	4,361
A8.3E & R	4	523	2,092
A5.8D & U	15	355	5,325
			$82,491
Credit for Feeder Pairs Between CO and A4A			
A4A	153	(235)	(35,955)
Subtotal Cable			$46,536

SAI Location	Circuit Quantity	Cost per Circuit	Extended Cost
For Circuits Longer Than 32 kf or A11A From The RST, LE/VFR Are Required			
LE/VFR	53	$187.5	$9,938
Credit for Load Coils 49 Not Required Between RST and Load Point #8			
49 X 1.25 (Adjustment Factor X $5 per LC)			(306)
TOTAL RST DESIGN @ A4A			$91,205

Comparison: RST at A4A versus GSC Design

RST is $\frac{\$91,205 - \$56,390}{\$56,390} \times 100 = 61.7\%$
Higher Than Station Carrier Design

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GSC Design versus RST at A5.8A

Use GSC Feeder Circuit Costs from A4A Study

SAI Location	Circuit Quantity	Cost per Circuit	Extended Cost
-	102	-	$39,238
	Physical Feeder Circuit Costs		
A7.3A & E	4	$456	1,824
A5.8A & T	15	268	4,020
	19		$5,844
Total Ckts:	121		
LE/VFR	1	$187.5	188
TOTAL GSC DESIGN @ A5.8A			$45,270

SAI Location	Circuit Quantity	Cost per Circuit	Extended Cost
		RST Cost	
A5.8A	121	$287	$34,727
		Feeder Circuit Cost Beyond RST	
A11.7A	10	$750	$7,500
A10.4A & P	13	663	8,619
A9.3A & H	15	590	8,850
A8.7A, F & G	7	549	3,843
A8A	7	503	3,521
A7.3A & E	4	456	1,824
A5.8A & T	15	355	5,325
A11F	12	704	8,448
A9F	4	570	2,280
A11.5G & N	16	737	11,792
A9.5G & J	7	603	4,221
A9.7J & Q	7	623	4,361
A8.3E & R	4	523	2,092
	121		$72,676
Credit for Feeder Pairs from CO to:			
A5.8A	121	(268)	(32,428)
Subtotal			$40,114
Credit for Load Coils Not Required Between RST and Load Point #9.8			
61 X 1.25 X 5			(381)
TOTAL RST DESIGN @ A5.8A			$74,594

Comparison of RST at A5.8A versus GSC Design

RST is $\frac{\$74,594 - \$45,270}{\$45,270} \times 100\% = 64.8\%$
Higher than GSC Design

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SAI Location	Circuit Quantity	Cost per Circuit	Extended Cost
GCS Design versus RST at A7.3A			
		GSC Cost	
-	102	-	$39,238
		Feeder Circuit Cost	
A7.3A & E	4	$456	1,824
LE/VFR	1	187.5	188
TOTAL GSC DESIGN @ A7.3A			$41,250
		RST Cost for A7.3A	
A7.3A	106	$172	$18,232
		Feeder Circuit Cost Beyond RST	
A11.7A & K	10	$750	7,500
A10.4A & P	13	663	8,619
A9.3A & H	15	590	8,850
A8.7A F, & G	7	549	3,843
A8A	7	503	3,521
A7.3A & E	4	456	1,824
A11F	12	704	8,448
A9F & V	4	570	2,280
A11.5G & N	16	737	11,792
A9.5G & J	7	603	4,221
A9.8J & Q	7	623	4,361
A8.3E & R	4	523	2,092
	106		$67,351
A7.3A	106	(456)	(48,336)
Subtotal Cable			$19,015
Credit for Load Coils Not Required Between RST and Load Point #11.3			
125 X 1.25 X ($5) =			(781)
Total RST Design @ A7.3A			$36,466

Comparison of RST at A7.3A

$$\frac{\$36,466 - \$41,250}{\$41,250} \times 100\% = -11.6\%$$

or 11.8% Lower than Station Carrier Design

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GSC Design versus RST at A8A

SAI Location	Circuit Quantity		Cost per Circuit	Extended Cost
		GSC Feeder Circuit Cost		
-	102		-	$39,238
		Physical Feeder Circuit Cost		
-	0		-	0
TOTAL GSC DESIGN @ A8A				$39,238
RST Cost for A8A:				
A8A	98		$172	$16,856
A11.7A & K	10		750	7,500
A10.4A & P	13		663	8,619
A9.3A & H	15		590	8,850
A8.7A, F, & G	7		549	3,843
A8A	7		503	3,521
A11F	12		704	8,448
A9F	4		570	2,280
A11.5F & V	16		737	11,792
A9.5G & J	7		603	4,221
A9.9J & Q	7		623	4,361
	98			$63,435
A8A	98		(503)	(49,294)
Physical Feeder Circuits to Match GSC Design				
A8.3E & R	4		523	2,092
Subtotal Cable				$16,233
LE/VFR's for Above	4	X	$187.5	$750
Credit for LC Not Required				
121 X 1.25 ($5)				(756)
TOTAL RST DESIGN @ A8A				$33,083

Comparison:

RST is $\frac{\$33,083 - \$39,238}{\$39,238}$ X 100% = 15.7 % Lower Than GSC Design

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GSC Design versus RST A8.7A

SAI Location	Circuit Quantity	Cost per Circuit	Extended Cost
		GSC Feeder Circuit Cost	
-	102	-	$39,238
TOTAL GSC DESIGN @ A8.7A			$39,238
RST Cost for A8.7A:			
($25,000 Common Eq. + (8 X $667 Span Eq.) - (91 * $190 VF Credit))			
X 1.25 + $549 X 6 pairs = $19,602			
A8.7A	91	-	19,602
		Feeder Circuit Cost Beyond RST	
A11.7A & K	10	$750	$ 7,500
A10.4A & P	13	663	8,619
A9.3A & H	15	590	8,850
A8.7A, F & G	7	549	3,843
A11F	12	704	8,448
A9F & V	4	570	2,280
A11.5G & J	16	737	11,792
A9.5G & J	7	603	4,221
A9.8J & Q	7	623	4,361
	91		$59,914
Credit			
A8.7A, F & G	91	($549)	($49,959)
Physical Feeder Circuits Inside A8.7A to Match GSC Design			
A8A	7	$503	$3,521
A8.3E & R	4	523	2,092
Subtotal Cable			$15,578
LE/VFR's for Above	11	187.5	2,063
Credit for Load Coils			
144 * 1.25 X ($5) =			(900)
TOTAL RST DESIGN @ A8.7A			$36,333

Comparison:

RST is - $\frac{\$36,333 - \$39,238}{\$39,238}$ X 100% = 7.4% Lower Than Grouped Station Carrier Design

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Based upon the above comparisons the following conclusions can be made: It is not economical to place an RST at A4A or A5.8A. It is economical to place a RST at A7.3A, A8A, or A8.7A. A8A is the most economical location. However, A8.7A is a more practical location. It is the junction point of the A, F, and G routes. It is likely that none of the loops starting from an RST at that location will require loading. In addition, it may be economical to backfeed additional subscriber circuits into the A8.7A location, lowering the overall cost per line. The next step is to determine which loops should be backfed into the SAI.

PHASE II: Backfeed the RST versus CO cost comparison. First a study should be made comparing the cost of a circuit from the central office to that of one from the RST. A sample cost comparison is tabulated as follows:

FEEDER CIRCUIT COSTS

Design Area	From C.O.			From RST		
	Pair	LE/VFR	Total	Pair	Line	Total
A8A	503	188	691	47	0	0
A7A	436	-	436	114	0	114
A8E	503	188	691	151	0	161
A6A	369	-	369	181	0	181
A5A	302	-	302	248	0	248
A6T	369	-	369	208	0	208
A4.5A	268	-	268	281	0	281
A7D	436	-	436	449	163	612
A4A	235	-	235	315	150	465

In the above costs the pair cost from CO for feeder circuits is the same as the physical circuit cost developed in Phase I. The LE/VFR cost is equal to $150 per unit times the 1.25 carrier adjustment factor. For the RST the pair cost is developed using the same methods that were used in Phase I except that the calculations begin at A8.7A and proceed towards the CO. The line cost is the incremental cost for each additional line added to the RST. For up to 128 lines, it is 0. Above 128 lines an additional $3000 in common equipment is required. To serve the D route, the incremental cost would be $3000 - (151-128) X 1.25 adjustment factor = $163. To serve as far as A4A incremental cost = $3000 - (153-128) X 1.25 factor = $150. The dividing line between the CO's and the RST's serving areas is somewhere between A4.5A and A5A. A4.7A would make a good dividing line. It is 18 kf from the RST. All of the circuit backfed into the RST would be nonloaded. The D route's loops would remain with the CO since they require loading.

PHASE II: Design beyond break-even point, refer to Figures 13a, 13b, and 13c. Locate RST and SAI at A8.7A. Since this is a permanent pair gain application and the RST is in effect at a new wire center, renumber the cable branches and load points with the RST and not the central office as the starting point. For example, A8A is a shifted two-tenths of a load section and becomes A1AX.

A7.3A becomes A2AX. (Note: The cable branch was not exactly at A8.7A. If it had been, A7.3A would have become A1.9A.) Use arrows in the backfeed portion to indicate that loops are being backfed into the RST's SAI. Show the equipped capacity (126) over the wired capacity (128). Indicate the span line pairs (6). Show the distribution pairs at the SAI (A route, 43; F route, 16; G route, 32; and AX route 35). Calculate the required pairs. Between A1AX and the A0AX there are 35 distribution pairs that are being backfed into the RST/SAI and 6 span line pairs, totaling 41 pairs required. Recalculate the cable pair sizes. Between A1AX and A0AX, 41 pairs required times 1.42 fill factor equals 59 pairs. Cross out 150 pair cable, indicate 75 pair cable.

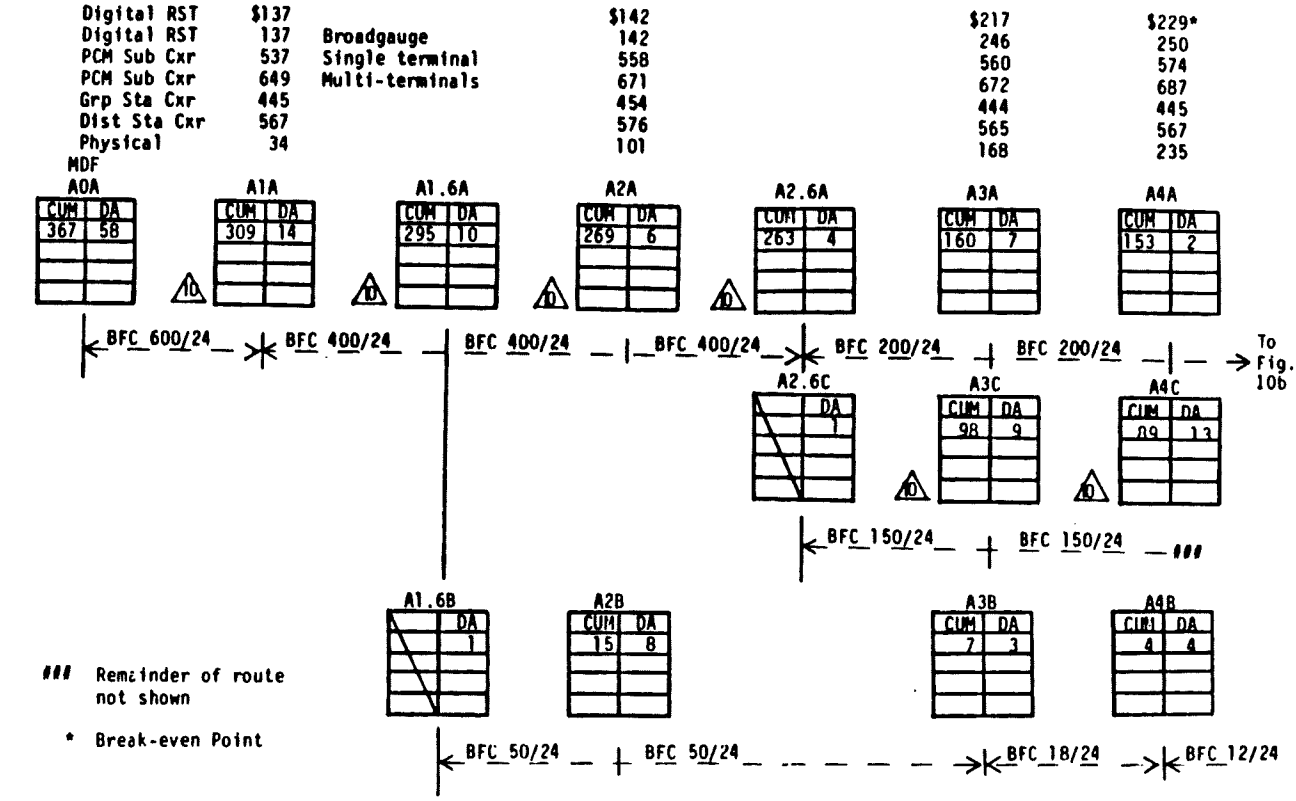
PHASE III: Design inside break-even point, Figure 14a. Locate SAI's A2.6A & C, A4.5A & D, and A5.8D & U. (A4.5A & D and A5.8A & U are not shown.) Show distribution and feeder pairs at each SAI. Show required pairs and recalculate cable pair sizes.

PHASE IV: Engineering judgment changes, pairs for installer and type housing SAI's. Refer to Figures 15a and 15b, which includes only the RST's serving area. In Figure 15b the portion between the RST (old A8.7A) and the central office's serving area (A4.7A or XA4.5AX) has been redrawn and labeled. An X has been placed in front of the route letter A to differentiate between the areas served by the RST and that served by the central office.

Indicate pairs available to the installer outside of the distribution pairs block. In this example the same fill factor used to determine cable size was used to calculate the installer pairs. In Figure 15b the required pairs at XA0A is 43; therefore, the fill factor is 1.42. The distribution pair quantity is also 43. Forty-three times 1.42 = 61.06. Write 62 beside the distribution pair block.

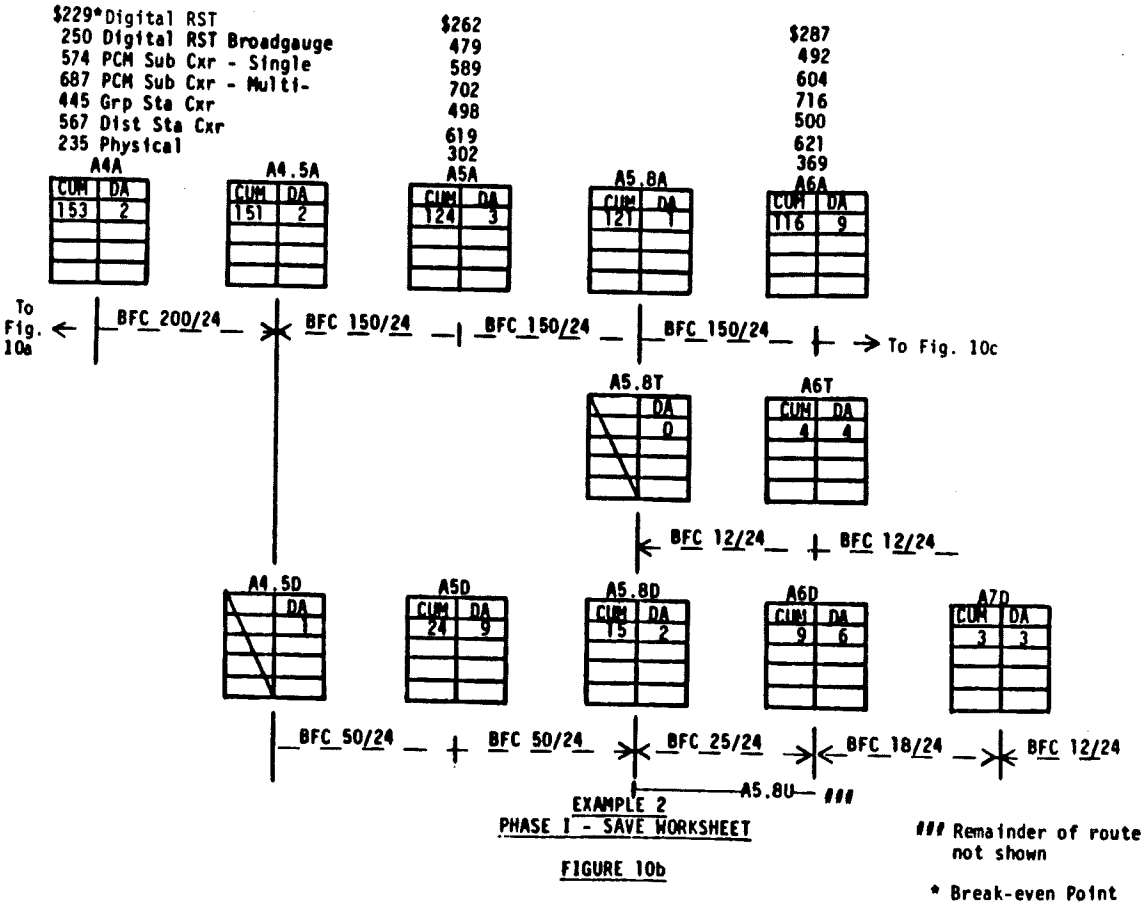
In Examples 1 and 2 the calculation of distribution pair requirements has been done using the cable selection table or the fill factor tables. These examples involve cables in variable growth area with mixed complements of distribution and feeder pairs. In the case of 'planned communities' the distribution pair requirements should be sized to provide two pairs for each establishment expected in the next 25 years. If feeder pairs are also required, the cable pair size should reflect the cables economic life and feeder circuit growth rate. For example, if a design area encompassed 25 25-year establishments and 10 five-year pairs passed through it, then a 75 pair cable would be the appropriate choice. A 75 pair cable should not be added to for at least 11 years (Table 6). At a medium growth rate of 6%, it can be projected that in 11 years 15 feeder pairs would be required ($10 \times 1.06^{11-5}$). The total requirement would be 50 distribution plus 15 feeder, totaling 75 pairs.

Show pairs reserved for carrier outside of the distribution block. At XA0AX, Figure 15b, 9 pairs have been reserved for carrier (6 X 1.42 fill factor). Consider using screened cables for new feeder cable installations.



EXAMPLE 2
PHASE I - SAVE WORKSHEET

FIGURE 10a

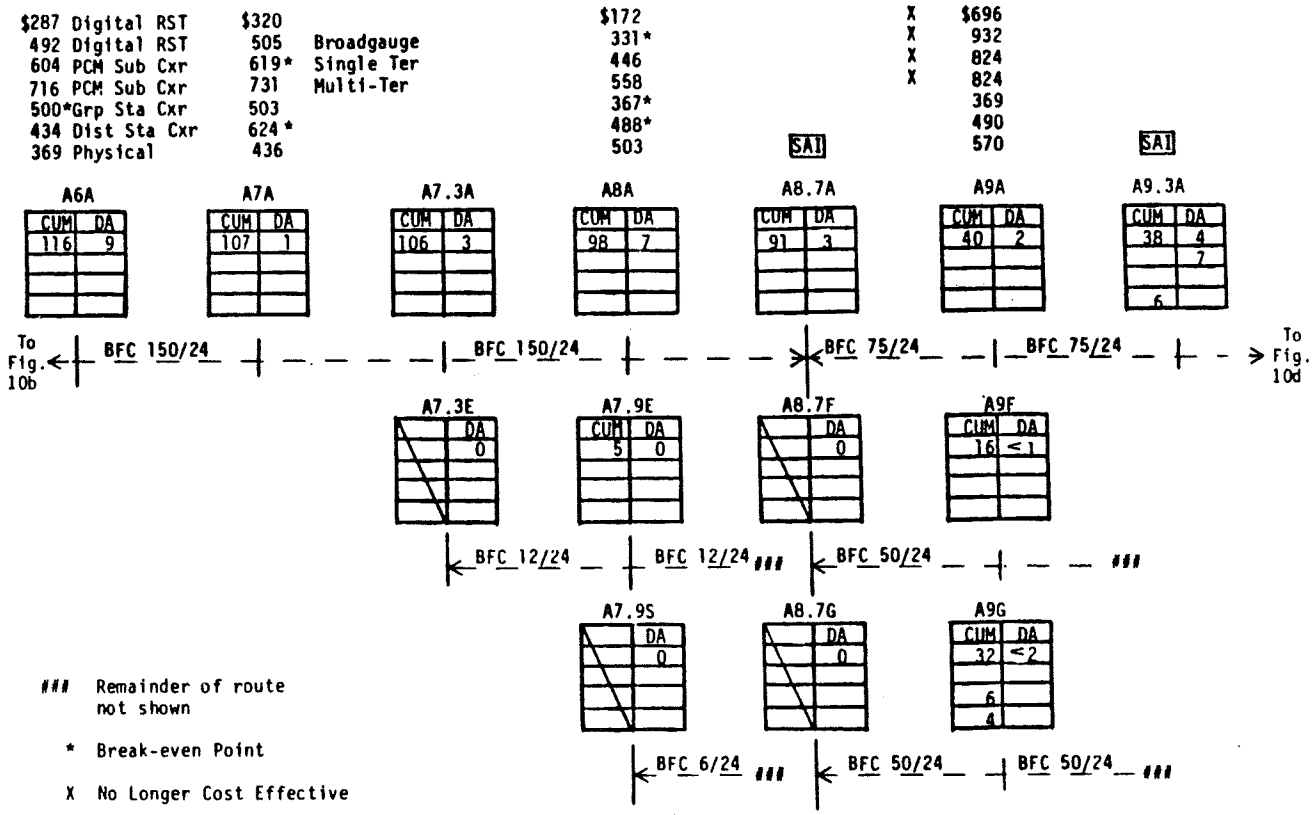


EXAMPLE 2
PHASE I - SAVE WORKSHEET

FIGURE 10b

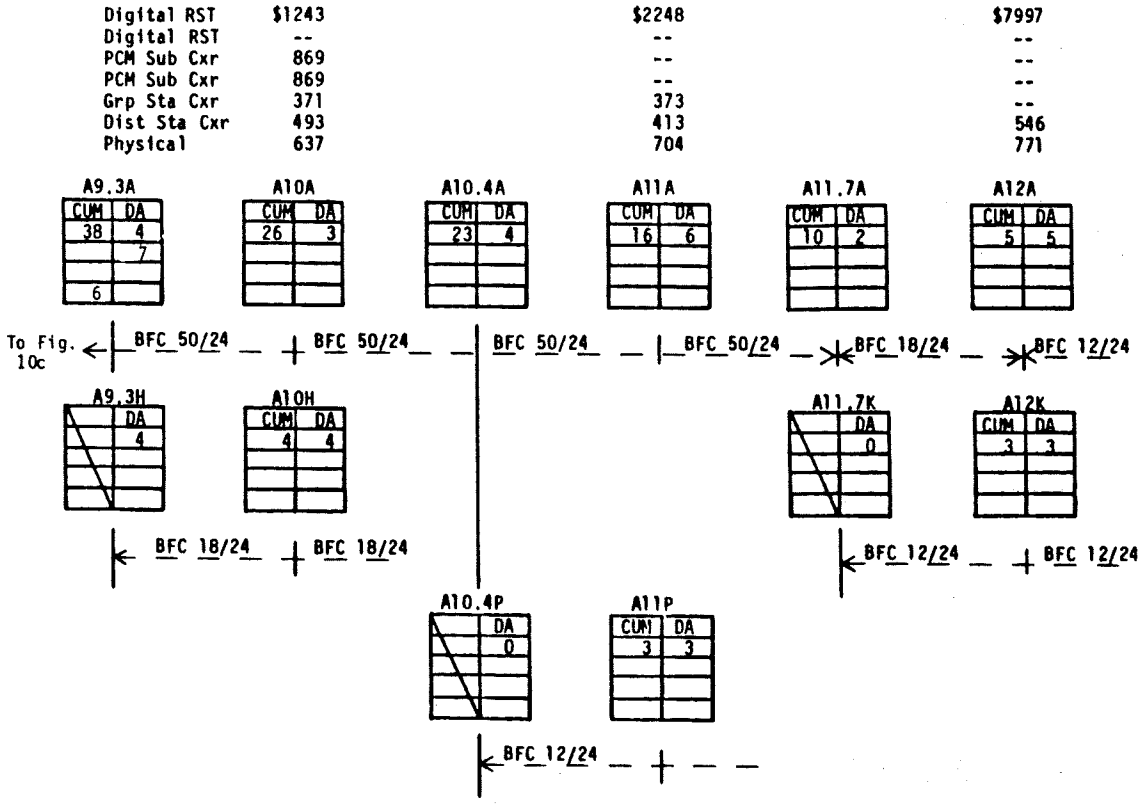
Remainder of route not shown

* Break-even Point



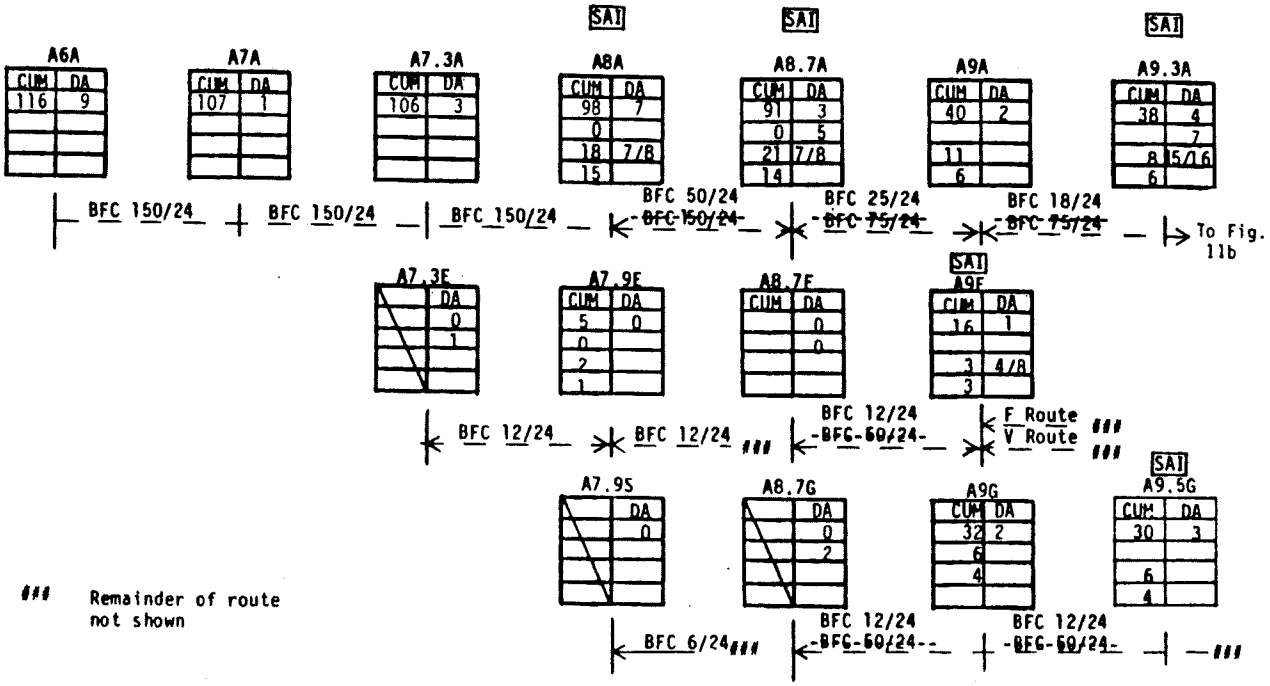
EXAMPLE 2
PHASE I - SAVE WORKSHEET

FIGURE 10c



EXAMPLE 2
PHASE I - SAVE WORKSHEET

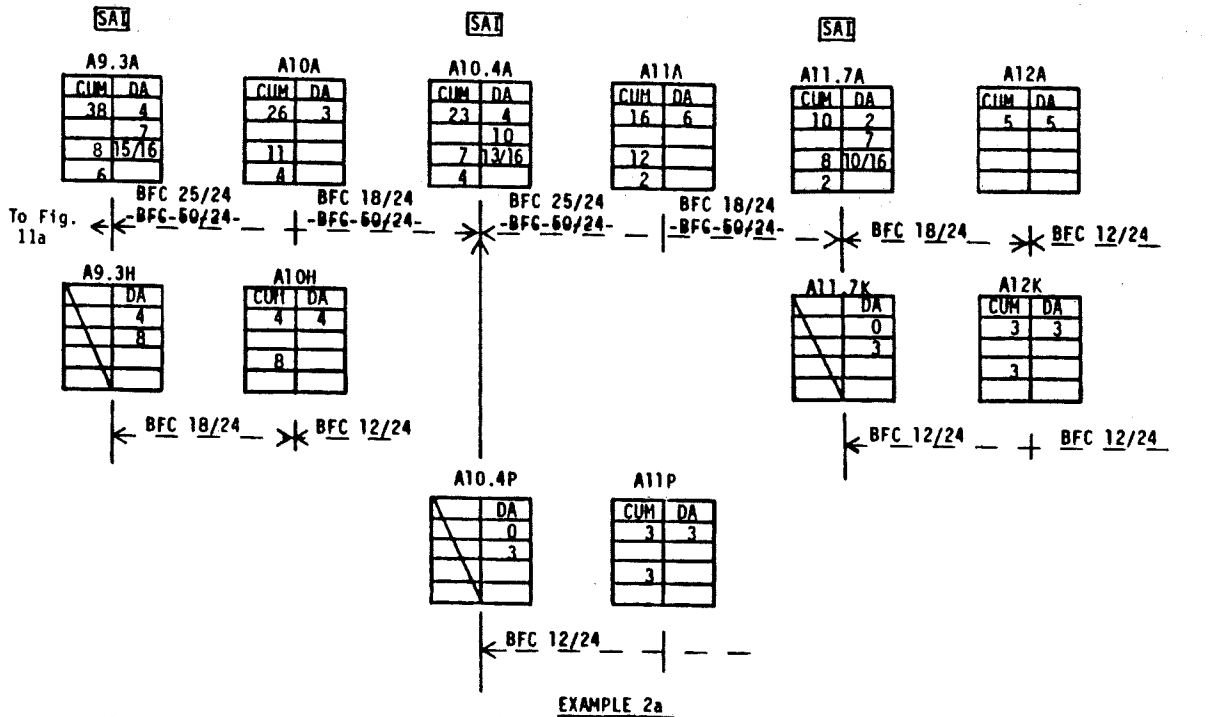
FIGURE 10d



Remainder of route not shown

EXAMPLE 2a
PHASE II - SAVE WORKSHEET

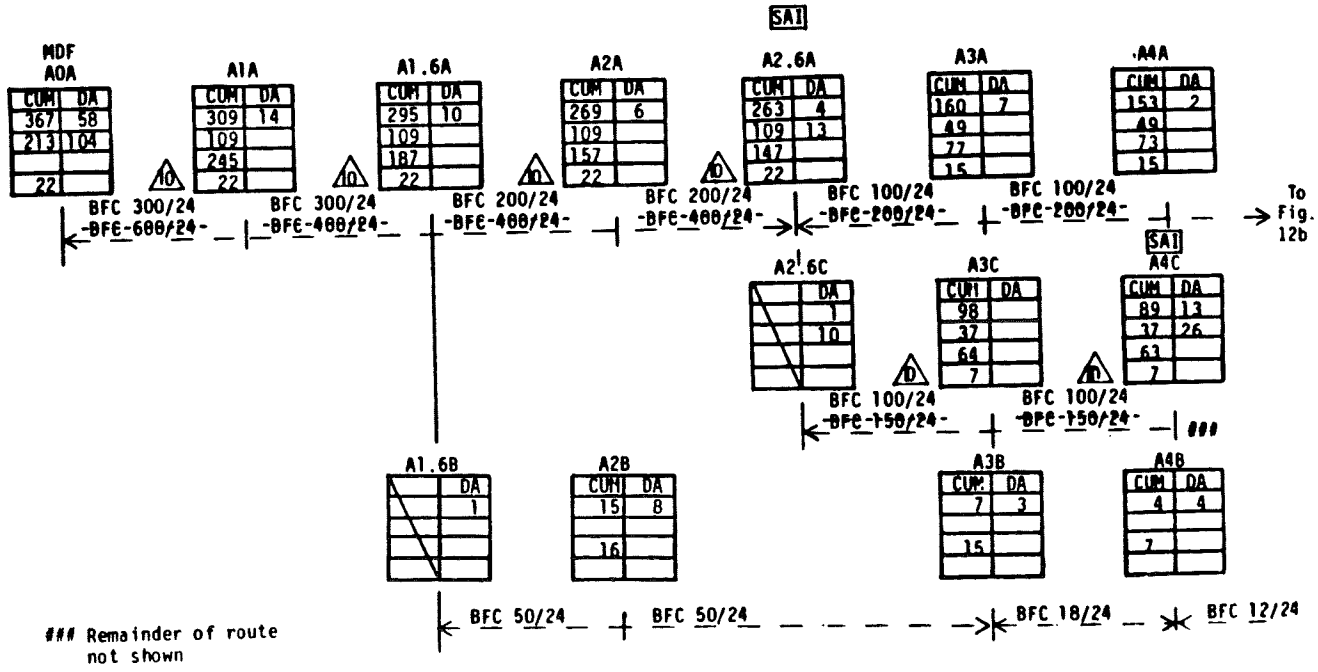
FIGURE 11a



EXAMPLE 2a
PHASE II - SAVE WORKSHEET

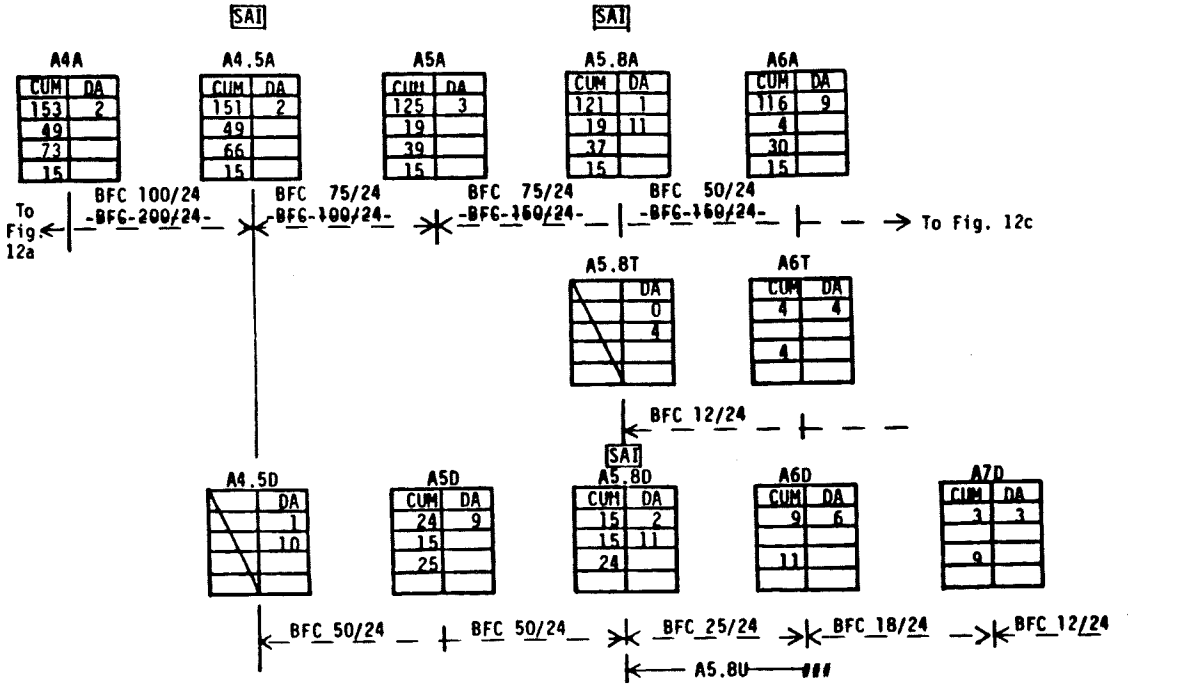
Using Grouped Station Carrier

FIGURE 11b



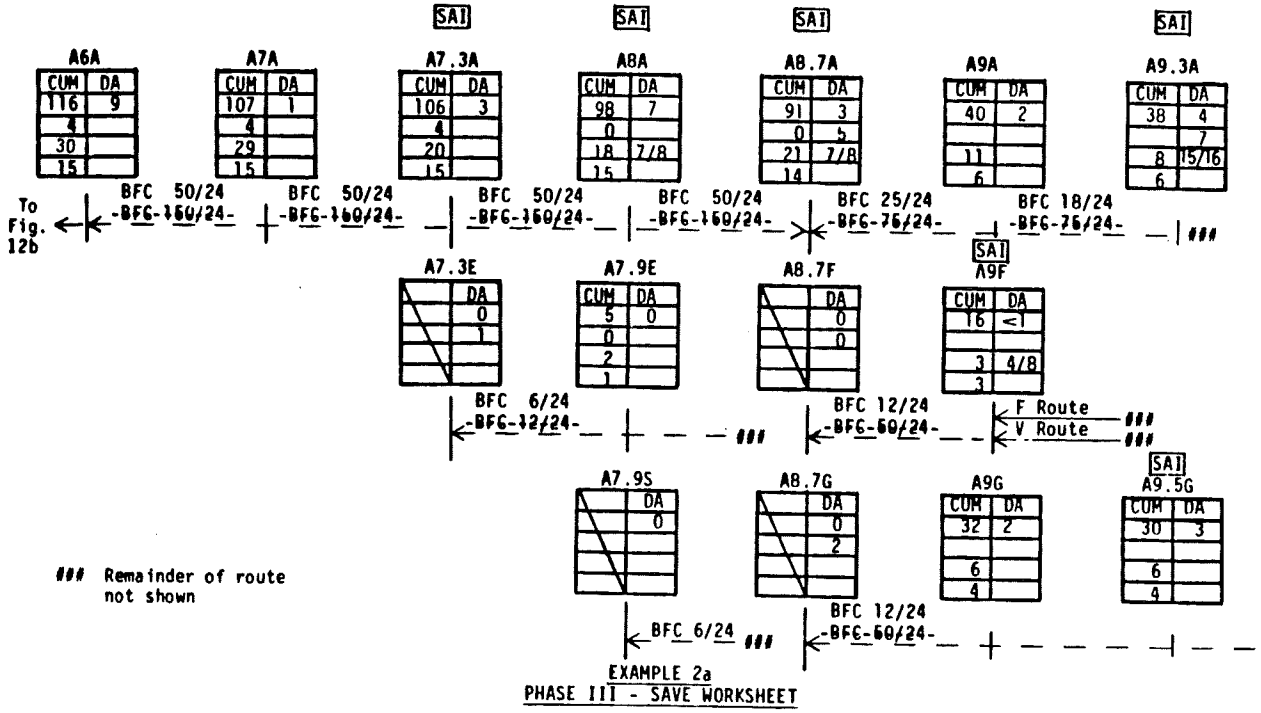
EXAMPLE 2a
PHASE III - SAVE WORKSHEET

FIGURE 12a



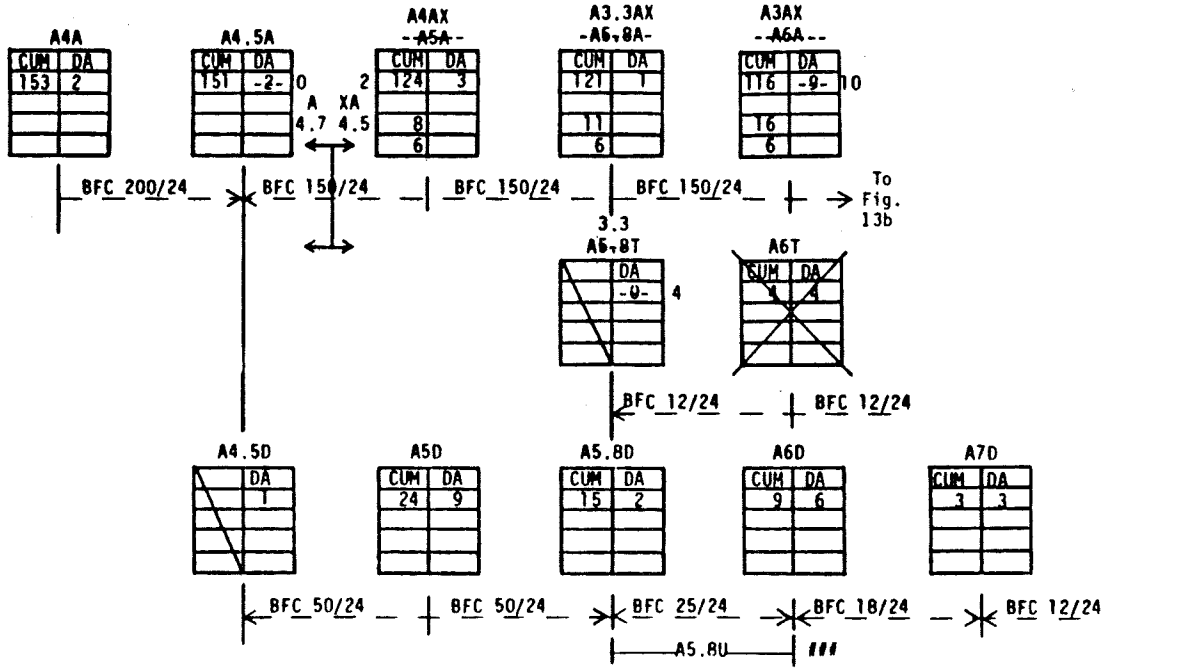
EXAMPLE 2a
PHASE III - SAVE WORKSHEET

FIGURE 12b



EXAMPLE 2a
PHASE III - SAVE WORKSHEET

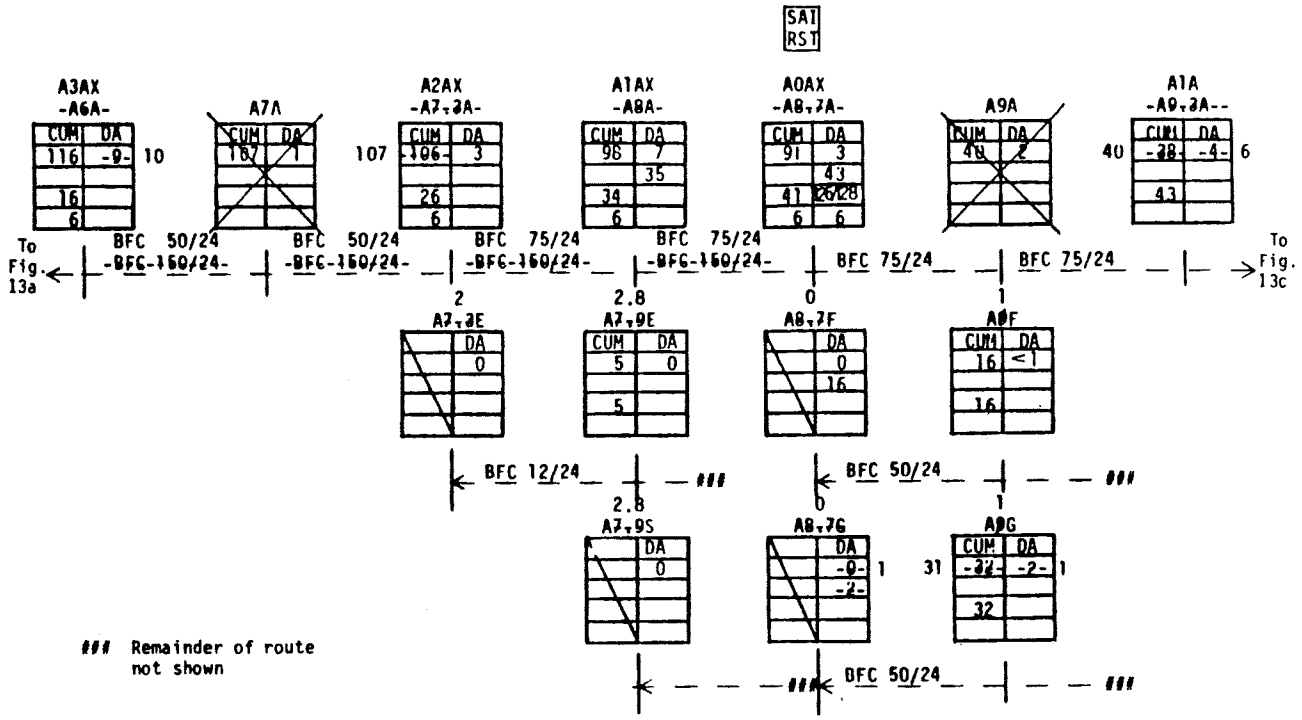
FIGURE 12c



EXAMPLE 2b
PHASE II - SAVE WORKSHEET

Remainder of route not shown

FIGURE 13a



EXAMPLE 2b
PHASE II - SAVE WORKSHEET

Remainder of route not shown

FIGURE 13b

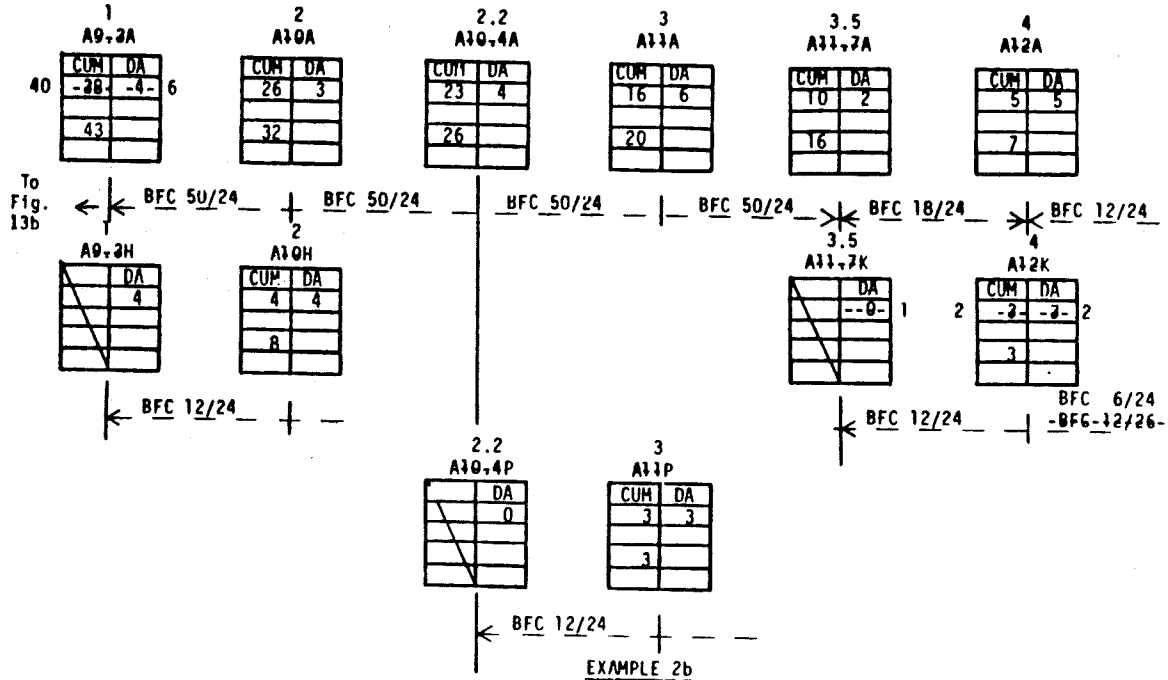


FIGURE 13c

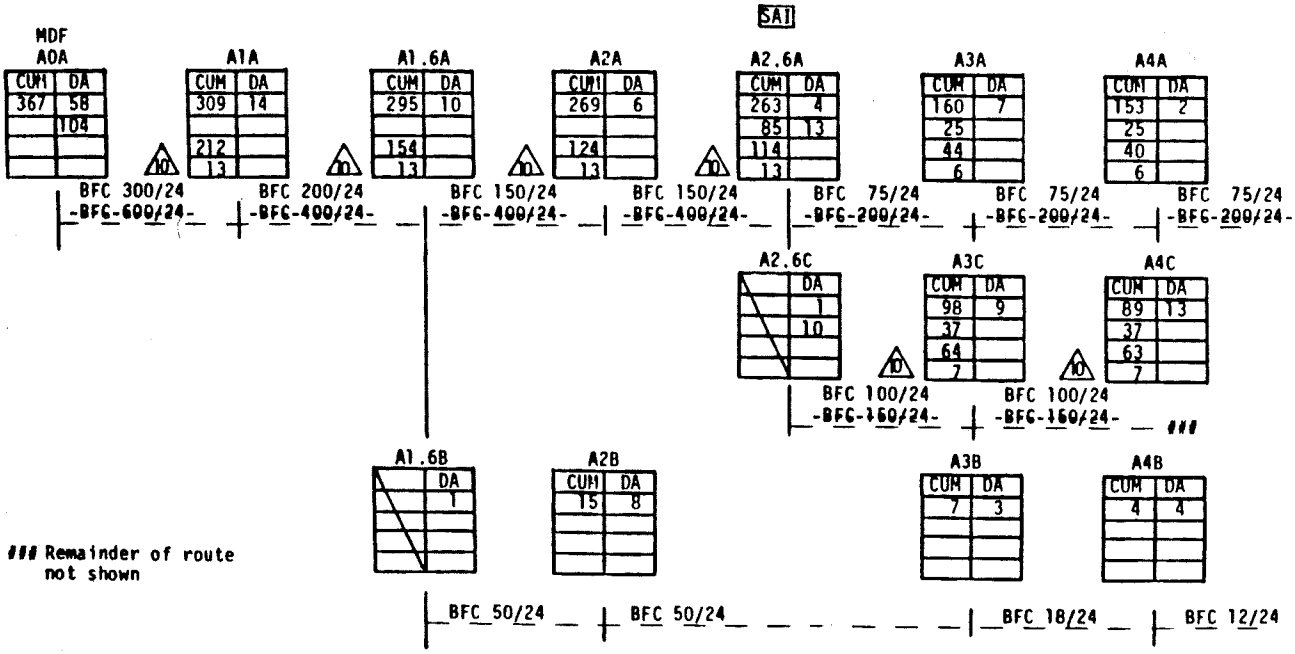
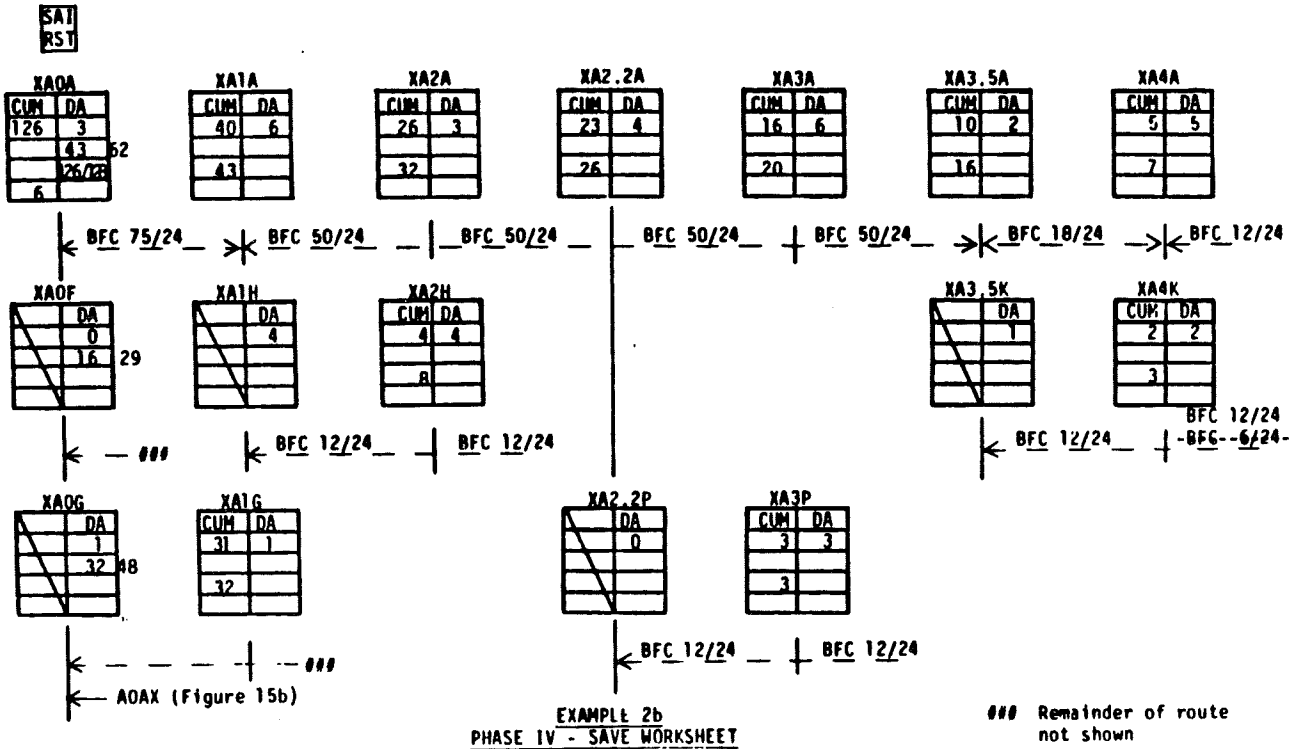


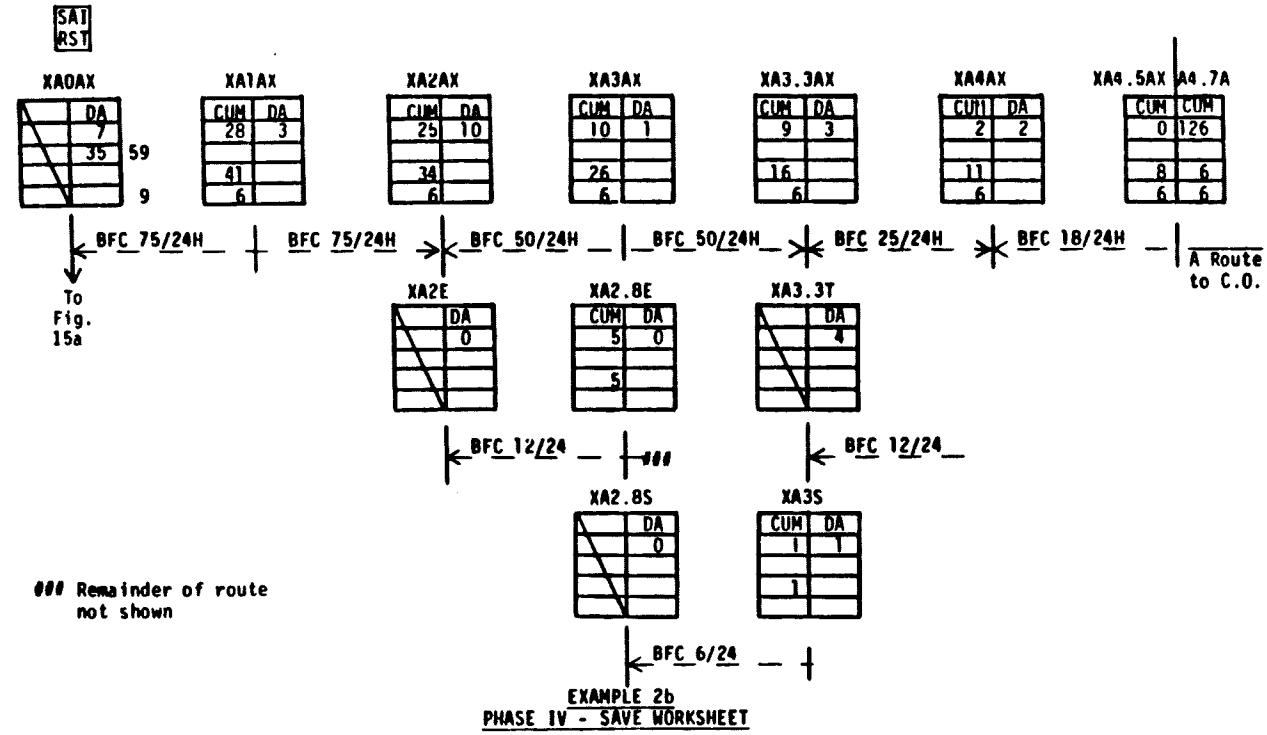
FIGURE 14a



EXAMPLE 2b
PHASE IV - SAVE WORKSHEET

Remainder of route not shown

FIGURE 15a



Remainder of route not shown

EXAMPLE 2b
PHASE IV - SAVE WORKSHEET

FIGURE 15b

APPENDIX 3

ONE LARGE CABLE VERSUS TWO SMALL CABLES

In building cable plant, it may be more economical to install one large cable now rather than a small one now and another small one later. A decision between these two alternatives should be based on present worth of annual charges (PWAC) analysis.

Table A shows the number of years required between the installation of two equally sized small cables before they will prove more economical than installation of one large cable initially.

This table is based on a number of assumptions. Each borrower should consider his own requirements and vary these assumptions as needed. The assumptions are:

1) Cable costs are as in Table 1 of this section, TE&CM 231.

2) Cost of money is 10%.

3) Cable life is 25 years.

4) The cost of future cable increases at a rate of 8% per year, compounded annually.

5) Cable annual charges are 16.8% of the initial cost (when depreciated over 25-year period).

6) The service life of the cables is expected to be 25 years.

7) The cables are replaced "in-kind".

Since the annual charge rate is 16.8%, the annual charge for the larger cable will be

.168 X installed cost of larger cable (ICLC).

The present worth of these annual charges is

$(P/A)\ {}^{10}_{25}$ = Present worth of an annuity (or present worth of a uniform series of payments) for 25 years at 10% cost of money.

This cable must now be compared with the present worth of annual charges for the two small sized cables.

The PWAC for the first small cable is

$(P/A)\ {}^{10}_{25}$ X (.168 X installed cost of smaller (ICSC) cable)

For the second cable, no annual charges are incurred until it is installed. If it is installed N years later the PWAC savings is

$$(P/A)\ {}^{10}_{N} \times (.168 \times (1.08)^N \text{ installed cost of the first smaller cable.})$$

where

$(P/A)\ {}^{10}_{N}$ is the present worth of annual charges at 10% for N years and $(1.08)^N$ is an inflation factor. (Second cable is installed N years later.)

Thus the total PWAC of the second small cable is

$$(P/A)\ {}^{10}_{25} \times (.168 \times (1.08)^N \times ICSC) - (P/A)\ {}^{10}_{N} \times (.168 \times (1.08)^N \times ICSC)$$

or

$$(.168 \times (1.08)^N \times ICSC \times (P/A)\ {}^{10}_{25} - (P/A)\ {}^{10}_{N}$$

If N is small, (the second small cable cannot be deferred for very long) it will be more economical to install a larger cable immediately. As N increases, the PWAC of the two cable plan decreases.

At a certain year N, the PWAC of the two plans will be equal. This year is termed the break-even year. At any point beyond this, the two cable plans will be more economical. By equating the PWAC for the two plans, we can find how many years the second small cable must be deferred before it will prove economical.

PWAC of large cable = PWAC of small cable + PWAC of second small cable.

$$(P/A)\ {}^{10}_{25} \times (.168 \times ICLC) = (P/A)\ {}^{10}_{25} \times (.168 \times ICSC + (P/A)\ {}^{10}_{25} - (P/A)\ {}^{10}_{N} \times (.168 \times (1.08)^N \times ICSC)$$

By solving this equation for $(P/A)_N$ we can find number of years the second cable must be deferred by looking up the value of $(P/A)_N$ in interest tables found in most engineering economy texts. $(P/A)\ {}^{10}_{25} = 9.077$

$$(P/A)\ {}^{10}_{N} = \frac{9.077 \times (ICSC - ICLC)}{(1.08)^N \times (ICSC)} + 9.077$$

This formulation is used in the SAVE guidelines in determining percentage fill required for various growth rates and for various cable sizes. Essentially, a cable is installed at such a percentage fill that it will not need to be reinforced until it is economical to do so with another equally sized cable (based on a PWAC analysis).

TABLE A

BREAK-EVEN YEARS FOR VARIOUS CABLE SIZES

PLAN I Install 4.5 kf small cable initially and reinforce with an equal size cable after an economical deferral period. Assume future cable cost increases 8% annually.

PLAN II Install large cable initially which will have a 25-year life but not necessarily provide all the circuits required for 25 years.

Using present worth of annual charges technique, find the minimum deferral period for the small reinforcing cable.

Large Cable versus Two Small Cables	Installed First Cost (Large Cable)	Installed First Cost (Small Cable)	Break-even Year (N)	Maximum 5-Year Cable Fill (%) Low (2%)	Med. (6%)	High (8%)
12-24 vs (6-24)+(6-24)	$ 2,544	$ 2,177	22+	74.1%	37.1%	27.0%
25-24 vs (12-24)+(12-24)	3,527	2,544	17+	78.8%	50.0%	39.7%
50-24 vs (25-24)+(25-24)	5,151	3,527	16+	80.4%	52.7%	42.9%
75-24 vs (50-24)+(25-24)	6,875	5,151/3,527	15+	82.0%	55.8%	46.3%
100-24 vs (50-24)+(50-24)	8,300	5,151	12+	87.1%	66.5%	58.3%
150-24 vs (75-24)+(75-24)	11,300	6,875	11+	88.8%	70.5%	63.0%
200-24 vs (100-24)+(100-24)	14,700	8,300	7+	90.0%	90.0%	90.0%
300-24 vs (150-24)+(150-24)	21,500	11,300	3+	90.0%	90.0%	90.0%
400-24 vs (200-24)+(200-24)	28,500	14,700	2+	90.0%	90.0%	90.0%
600-24 vs (300-24)+(300-24)	42,000	21,500	1+	90.0%	90.0%	90.0%

The SAVE guidelines assume the following growth percentages (compounded annually):

Low Growth	=	2%
Medium Growth	=	6%
High Growth	=	8%

In some cases the PWAC technique will show cable fills of greater than 90% at the end of five years. In order to allow for bad pairs, inaccuracies in forecasts, etc., no cable is filled to more than 90% after five years under these guidelines. Table A lists the results of these calculations for various cable sizes.

Example:
Table A shows that the break-even years for two 12-pair cables vs one 25-pair cable is 17 years. This means that a 12-pair cable should be installed at such a percentage 5-year cable fill that it won't need reinforcement for 17 years.

In a medium growth area (6% growth), the number of subscribers at the end of 17 years will be 17-year subscribers = existing subscribers X $(1.06)^{17}$

or

17-year subscribers = 5-year subscribers X $(1.06)^{12}$

In general, the cable fill formula is:

% Fill after 5 years = $(1+P)^{5-N}$

where

P = Percent growth of area (expressed as a decimal)

N = Break-even year from Table A

It is is assumed that the cable be filled at the end of the 17 years, the five-year percent fill is $(1.06)^{-12}$ or 50%.

This same process was repeated using the appropriate break-even year from Table A to produce Table B which is the cable fill percentages for various size cables at the assumed economic factors cited.

The number of pairs required for a 50% filled cable at the end of five years can be obtained by multiplying the five-year subscribers by $\frac{1}{.50} = \frac{1}{.50} = 2.00$.
This is the number recorded in Table 9. Because it is desired to record one factor for a range of cable sizes in the table, it will be necessary to round off between the different values for different cable sizes within a range.

For convenience in applying the fill factors to the SAVE design, the fill factors shown in Table 9 are plotted against the number of five-year circuits

rather than cable size. For example, in medium growth areas calculations like those above show the maximum fill for a 6-pair cable should be 37.1%, for a 12-pair cable 50%, a 18 or 25-pair cable 52.7%, etc. Thus, the largest number of subscribers that can be served by a 12-pair cable is six. The largest fill factor number for a 6-pair cable is two. If there are between three and six subscribers in a design area, they would be multiplied by 1.5 or 2 to determine the pairs required. Since seven subscribers cannot be served in a 12-pair cable at 50% fill, they would require the placement of a larger cable. Since cables of 18 and 25 pair have a maximum fill of less than 52.7% in medium growth areas, five-year subscribers between seven and 17 would be multiplied by 1.527 or 1.90. Even though 52.7% of 25 = 13, 14 is included in the range. If 14 had been included in the 1.79, the wrong cable may have been selected since 1.79 X 14 = 25.06 and 14 subscribers on a 25 pair cable is a 56% fill. The thresholds thus determined the medium growth rate areas are applied to all growth rate areas after some rationalization. The thresholds could have been developed using the low or high rates, but by using the medium growth rate a reasonable compromise threshold was used. If a design is contemplated that has growth rates outside the low or high growth rates, a fill factor table for that particular situation should be developed.

MAXIMUM FIVE-YEAR
CABLE FILL PERCENETAGES
NEW CONSTRUCTION

CABLE SIZE (PAIRS)	GROWTH RATE		
	LOW (2%/Yr)	MEDIUM (6%/Yr)	HIGH (8%/Yr)
6	74.1	37.1	27.0
12	78.8	50.0	39.7
18	80.4	52.7	42.9
25	80.4	52.7	42.9
50	87.1	66.5	58.3
75	88.8	70.5	63.0
100	90.0	89.0	85.7
150 and up	90.0	90.0	90.0

APPENDIX 4

CARRIER ADJUSTED ANNUAL COST

During Phase I, Tables 2, 3, 4, and 5 (Carrier Adjusted Annual Cost) are used to determine the break-even points. This determination is made by comparing the cost of a physical circuit with the cost of a carrier circuit. The tables are a tabulation of the adjusted costs of the various carrier systems as a function of distance from the C.O.

While carrier costs do not vary as much with distance from the C.O. as do physical costs, longer systems do require more repeaters and perhaps intermediate power feeds. These factors must be taken into account in setting up the adjusted costs. For details of the derivation of the equipment and installation costs of carrier, see TE&CM Section 232, Appendix A.

The comparison of the cost of carrier with the cost of physical plant is to be done on an annual charges basis. In doing this it must be recognized that carrier annual charges are somewhat higher than physical plant annual charges. This is due to the fact that carrier has a shorter life and hence must be depreciated more rapidly as well as the fact that carrier is more expensive to maintain than physical plant.

In the adjusted cost the carrier cost is multiplied by a factor which accounts for these differences. While the tables given in the SAVE guidelines uses a factor of 1.25, it should be noted that this factor will vary between different borrowers. The derivation of the 1.25 factor presented below is typical of many borrowers. The consultant should derive different factors to fit the existing situation if necessary. Use annual cost factors, depreciation, maintenance, etc., based on actual experience.

ANNUAL COSTS

	Carrier	Physical
Depreciation (Sinking Fund)	1.7% (20 yr)	1.0% (25 yr)
Maintenance	5.0%	1.5%
Property Tax	2.0%	2.0%
Cost of Money[1/]	10.0%	10.0%
Federal Income Tax	2.3%	2.3%
	21.0%	16.8%

Carrier Adjustment Factor

$$\frac{21.0}{16.8} = 1.25$$

Certain items required in a physical design are, by their nature, subject to the same annual charges as are carrier facilities. These include load coils and electronic line treatment equipment such as loop extenders and VF repeaters. Because of this, the cost of these items is subtracted from the carrier cost prior to multiplying by the 1.25 factor.

[1/] 8% Interest and 2.0% return on equity (margin)

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