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VACUUM TUBE AVAILABILITY ASSESSMENT PROGRAM. (U)  
FEB 77 R M COSEL, G K HUDDLESTON, W D PEELE

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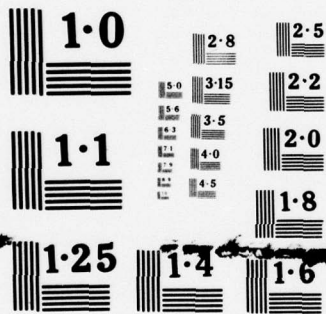
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VACUUM TUBE AVAILABILITY ASSESSMENT PROGRAM

R.M. Cosel  
G.K. Huddleston  
W.D. Peele



Final Report  
February 1977



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**U.S. DEPARTMENT OF TRANSPORTATION**  
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**Washington, D.C. 20590**

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| 16. Abstract<br>This report deals with the problem of the continued availability of vacuum tubes and solid state replacement devices to support representative FAA equipments through the 1980's. The reduced availability of vacuum tubes is due mainly to the massive transition to solid state equipment by the consumer entertainment industry. This action has led to a large reduction of vacuum tube suppliers, and to a significant increase in the cost of vacuum tubes. Price and tube demand data are presented for the selected VOR systems. The applicability of solid state replacement devices to the FAA equipments is discussed.<br>A second volume of this report contains the correlations of tube types with FAA equipment and vice versa. |  |  |           |
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## FOREWORD

This effort was conducted by Purdue University, Georgia Institute of Technology, and Florida Institute of Technology under the sponsorship of the Rome Air Development Center Post-Doctoral Program for the Federal Aviation Administration. Charles Andrasco of the Federal Aviation Administration was the task project engineer and provided overall technical direction and guidance.

The RADC Post-Doctoral Program is a cooperative venture between RADC and some sixty-five universities eligible to participate in the program. Syracuse University (Department of Electrical and Computer Engineering), Purdue University (School of Electrical Engineering), Georgia Institute of Technology (School of Electrical Engineering), and State University of New York at Buffalo (Department of Electrical Engineering) act as prime contractor schools with other schools participating via sub-contracts with the prime schools. The U. S. Air Force Academy (Department of Electrical Engineering), Air Force Institute of Technology (Department of Electrical Engineering), and the Naval Post Graduate School (Department of Electrical Engineering) also participate in the program.

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for Rome Air Development Center (RADC), Space and Missile Systems Organization (SAMSO), Aeronautical Systems Division (ASD), Electronic Systems Division (ESD), Air Force Avionics Laboratory (AFAL), Foreign Technology Division (FTD), Air Force Weapons Laboratory (AFWL), Armament Development and Test Center (ADTC), Air Force Communications Service (AFCS), Aerospace Defense Command (ADC), Hq USAF, Defense Communications Agency (DCA), Navy, Army, Aerospace Medical Division (AMD), and Federal Aviation Administration (FAA).

Further information about the RADC Post-Doctoral Program can be obtained from Jacob Scherer, RADC, tel. AV 587-2543, COMM (315)-330-2543.

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## CHAPTER 1

### INTRODUCTION

This investigation was directed at determining the availability of vacuum tubes for FAA operating equipments with an expected useable life through the 1980's. The findings are also applicable to DOD equipment of similar type. This study focuses on those tubes, receiving, small industrial and commercial types whose economics of manufacture has depended on the now rapidly dwindling mass original equipment manufacturer (OEM) and replacement market demand. The objectives of the present study are to assess the capability of industry to support FAA systems through this time period. This report addresses the problems of: (1) dependability of tube supply; (2) tube phase-out dates; (3) cost of tubes; (4) quality of tubes.

It is also required to recommend alternate approaches and to make the best possible determination of alternate methods of supporting existing equipment, e.g., (1) equipment modification so that available tubes can be used; (2) solid state replacement of tubes; (3) equipment modification to use solid state circuitry; (4) estimated cost of alternate methods; (5) assessment of the reliability of alternate approaches.

To accomplish the above tasks, it is necessary to investigate possible sources of vacuum tubes: the expected life of existing on-shore (U.S.) suppliers, off-shore (foreign) procurement, the value of the surplus market, the practicality and cost of DOD/FAA subsidizing tube manufacturers.

Toward these ends, the following actions have been taken. A cross reference of tube requirements vs. equipment types has been obtained from the FAA. The present availability, price data, and forecast demand for pertinent tube types has been obtained from the FAA Depot at Oklahoma City

and from the Defense Electronic Supply Center (DESC) at Dayton, Ohio. Analysis of these data are presented in Chapter 2. Preliminary investigations of the applicability of solid state replacements (SSR) for vacuum tubes in typical equipments have been initiated. The results thus far are presented in Chapter 3. Additionally, vacuum tube manufacturers have been contacted to obtain their assessment of the availability of tubes and changes in tube pricing.

Government concern for the problems that may be caused by the diminishing sources of vacuum tubes was first manifested officially in the formation of the DOD Ad Hoc Vacuum Tube Support Group in May, 1973. Appendix A summarizes the report issued by that group in June, 1975.

## CHAPTER 2

### VACUUM TUBE ANALYSIS

#### 2.1 Introduction

In order to provide a more detailed analysis of the vacuum tube problem, a typical FAA system was selected. The VOR system was considered a typical example and this chapter presents data concerning the vacuum tube requirements of the VOR equipments. In addition, explanations are presented for the lists in Volume II of this report which correlate all FAA tubes and equipment. The VOR equipments considered are presented in Section 2.2. The VOR tube types and quantities used are presented in Section 2.3. Cost and usage data are presented in Section 2.4. Section 2.5 presents the data concerning tube/equipment correlations for all FAA equipment.

The data presented in this chapter were collected from a variety of sources including FAA, ARD-350, FAA Depot (OKC), Defense Electronic Supply Center (DESC), AMEX, and from other FAA personnel interviewed in the field.

#### 2.2 VOR Equipments

The VOR equipments considered in the analysis are listed in Tables 2-1, 2-2, and 2-3. The equipments listed are those examined by AMEX in correlating tube types to equipments. The equipment quantity figures were provided by the FAA (ARD-350). It is assumed that the equipments and quantities listed are relatively complete and current.

The equipments are classified into the three tables according to type numbers. It was originally thought that this procedure would also classify the equipments according to age. Since the FAA type numbers (Table 2-3) were issued beginning 12/31/58 (and CA type numbers prior to then), it is assumed that Table 2-2 lists the older equipments (pre-1959). However, the vintage of the equipments in Table 2-1 cannot be established on the same basis since the letter type designations for transmitters appear to extend to 1966 (see Note 1 of Table 2-1).

TABLE 2-1. VOR EQUIPMENTS (PRE-CA NOS.)

| EQUIPMENT TYPE<br>DESIGNATION | EQUIPMENT                             | QUANTITY |
|-------------------------------|---------------------------------------|----------|
| TV-1                          | 230W VHF Omni-Range Transmitter (VOR) | 56       |
| TV-2                          | 50W Omni-Range Transmitter (VOR)      | -        |
| TV-4                          | 230W VHF Omni-Range Transmitter (VOR) | 78       |
| TV-7                          | Transmitter, Radio, VHF, 230W (VOR)   | 310      |
| TV-8                          | VHF Transmitter 200W (VOR)            | 130      |
| TV-12                         | VOR Transmitter, 200W                 | 160      |
| TV-19                         | VOR Transmitter, 200W                 | 160      |
| TV-27                         | VOR Transmitter, 200W                 | 169      |
| TV-31                         | VOR Transmitter, 200W                 | 164      |
| TUL                           | VHF Radio Transmitter (108-127 mc)    | 200      |
| TUM                           | VHF Radio Transmitter                 | 200      |
| TUO                           | VHF Radio Transmitter (108-118 mc)    | 236      |
| TUO-1                         | VHF Radio Transmitter (108-118 mc)    | 254      |

## NOTES:

1. Prior-1966 Usage. Two letters, hyphen, number; e.g., TV-1. T=Transmitter, V=Very High Frequency (3 to 30 mc).
2. Older Practice. Three letters; first letter T (or R), second letter U=old UHF band (approximate current VHF band).



TABLE 2-2. VOR EQUIPMENTS (CA TYPE NOS.)

| EQUIPMENT TYPE<br>DESIGNATION | EQUIPMENT                                  | QUANTITY |
|-------------------------------|--|----------|
| CA-663                        | Carrier Modulator, VHF                     | -        |
| CA-665                        | Carrier Modulator, Driver                  | -        |
| CA-694                        | Oscillator-Keyer Unit (1020 Cycle)         | 432      |
| CA-1201                       | Monitor Amplifier (VAR)                    | -        |
| CA-1295                       | Monitor Amplifier (VOR)                    | -        |
| CA-1296                       | Audio-Oscillator-Keyer (VOR)               | -        |
| CA-1330                       | Power Supply, Frequency Stabilized (VOR)   | 200      |
| CA-1340                       | Carrier Modulator Driver                   | -        |
| CA-1341                       | Carrier Modulator                          | -        |
| CA-1349                       | Locking Tone Keyer Oscillator              | 60       |
| CA-1396                       | Voice Frequency Amplifier                  | -        |
| CA-1402                       | Carrier Modulator Driver (ILS)             | -        |
| CA-1403                       | Carrier Modulator (ILS)                    | -        |
| CA-1421                       | Voice/Code Reproducer (VOR)                | -        |
| CA-1426                       | Volume Control and Speaker Switching Unit  | -        |
| CA-1479                       | Voice-Code Reproducer (VOR)*               | -        |
| CA-1485                       | Monitor, VOR                               | 40       |
| CA-1486                       | Regulated Output Audio Amplifier (VOR)     | 58       |
| CA-1564                       | VOR Test Signal Generator                  | 38       |
| CA-1567                       | Monitor Amplifier-VOR                      | 450      |
| CA-1568                       | 1020 Cycle Oscillator (VOR)                | 61       |
| CA-1575                       | VOR Monitor                                | 218      |
| CA-1589/A                     | Regulated Output Amplifier                 | 71       |
| CA-1600                       | 1020 Cycle Oscillator (VOR)                | 2295     |
| CA-1601                       | Regulated Output Audio Amplifier (VOR)     | 384      |
| CA-1608                       | Monitor Amplifier, VOR                     | 155      |
| CA-1611                       | Carrier Modulator Driver (VOR)             | 155      |
| CA-1612                       | Carrier Modulator (VOR)                    | 325      |
| CA-1616                       | VOR Monitor                                | 325      |
| CA-1628                       | VOR Test Generator                         | 163      |
| CA-1652                       | Monitor Amplifier (VOR)                    | 285      |
| CA-1765                       | VOR Monitor Equipment Input Selection Unit | 80       |
|                               |  | 84       |

TABLE 2-2. (CONTINUED)

| EQUIPMENT TYPE<br>DESIGNATION | EQUIPMENT  | QUANTITY |
|-------------------------------|--|----------|
| CA-1782                       | Regulated Output Amplifier (TOWERSCENTERS, INSACS) | 1575     |
| CA-2946                       | 1020 cps Oscillator (Converted CA-666) (VOR/DME)   | -        |
| CA-3410                       | VOR Counterpoise Detector                          | 488      |

\* Instruction books marked CA-1478; Equipment marked CA-1421A.



TABLE 2-3. VOR EQUIPMENTS (FA TYPE NOS.)

| FA TYPE<br>DESIGNATION | EQUIPMENT                                      | QUANTITY |
|------------------------|--|----------|
| FA-5155                | VOR Test Generator (VOR Test)                  | 147      |
| FA-5226/5303           | VOR Monitor Equipment Input Selection Unit     | 205      |
| FA-5238                | Regulated Output Amplifier (TOWERS, INSACS)    | 618      |
| FA-5257                | VHF Omirange Automatic Frequency Control Unit* | 40       |
| FA-5258                | VOR Frequency Deviation Monitor*               | 20       |
| FA-5328                | VOR Test Generator                             | 54       |
| FA-5341                | Voice/Code Reproducer Assembly (VOR)           | 40       |
| FA-5412                | Monitor Amplifier, VOR                         | 114      |
| FA-5414                | Audio Oscillator Keyer (VOR)                   | 597      |
| FA-5416                | VOR Carrier Modulator Driver                   | 177      |
| FA-5417                | VOR Carrier Modulator                          | 177      |
| FA-5424                | VOR Regulated Output Amplifier                 | 114      |
| FA-5427                | VOR Monitor Equipment Input Selection Unit     | 191      |
| FA-5428                | VOR Test Generator                             | 97       |
| FA-5429                | Voice/Code Reproducer Assembly (VOR)           | 136      |
| FA-5612                | VOR Monitor Amplifier                          | 42       |
| FA-5616                | VOR Carrier Modulator Driver                   | 87       |
| FA-5617                | VOR Carrier Modulator                          | 87       |

\* Doppler VOR

The data presented in Tables 2-1 through 2-3 are based in the main on FAA Order 0000.7A dated 15 April 1974 (Index of FAA Electronic Equipment Type Designations).

### 2.3 Tubes Used in VOR Equipments

Table 2-4 lists the tube types used in the VOR equipments listed in Tables 2-1 through 2-3. Column 1 lists the type cited in the instruction books; the latest tube designation carried on the FAA Depot stock lists is given in parenthesis. Column 2 gives the current Federal Stock Number.

The next four columns give the quantities of each tube type used in the equipments as classified in Tables 2-1 through 2-3. A "greater than" symbol (>) indicates that the data or equipment quantity was not complete; hence, the quantity of tubes required is greater than the calculated number shown. The last column indicates pertinent remarks.

Problem tube types are indicated in Table 2-4 by the horizontal lines. At this point in time, Table 2-4 indicates that the 3B28, 5Z3, 6A3, and 836 are non-procurable, obsolete, or not in the supply system. However, as indicated in the Remarks column, 3B28 has SSR IN2637, 5Z3 has SSR CP117 (ED1), and 836 has SSR CP131. But the 6A3 (triode, 4-pin base) has no known replacement; it is, however, electrically equivalent to the 6B4G (octal base). In short, there appear to be simple solutions for the problem tubes listed in Table 2-4 at the present time.

Attention should be drawn also to the metal tubes 6L6, 6SF5, and 6V6 which currently have no manufacturing source. However, the equivalent glass tubes are being produced. It is believed that the use of a metal shield with the glass tube in applications requiring shielding will

TABLE 2-4. TUBES USED IN VOR EQUIPMENTS.

| TUBE TYPE<br>(LATEST DESIGNATION) | CURRENT FSN<br>5960-00- | QUANTITY USED |         |       |         | REMARKS                                |
|-----------------------------------|-------------------------|---------------|---------|-------|---------|--|
|                                   |                         | PRE<br>CA     | CA      | FA    | TOTAL   |  |
| HK253                             | -188-8542               | 400           | 0       | 0     | 400     | TUL only                               |
| HK454H (250TH)                    | -114-3826               | 400           | 0       | 0     | 400     | TUL only                               |
| VR150 (VR150-OD3)                 | -188-8573               | 0             | 60      | 0     | 60      | CAL349 only                            |
| OA2 (OA2WA)                       | -503-4880               | 783           | 2,085   | 1,806 | 4,674   |  |
| OB2 (OB2WA)                       | -624-4718               | 366           | > 464   | 1,358 | > 2,188 |  |
| OC3                               | -188-0968               | 0             | > 536   | 0     | > 536   | CAL330, 1421, 1478, 1485, 1486         |
| IP39                              | -281-0798               | 0             | 40      | 0     | 40      | CAL478 only                            |
| IP40                              | -235-9124               | 0             | ?       | 0     | ?       | CAL421 only (1 ea.)                    |
| 12AL5                             | -878-1881               | 0             | 617     | 418   | 1,035   |  |
| 12AT7 (12AT7WC)                   | -179-4446               | 0             | 3,572   | 0     | 3,572   |  |
| 12AU6                             |                         | 444           | 8,682   | 4,060 | 13,186  |  |
| 12AX7 (12AX7WA)                   | -827-8782               | 0             | > 5,593 | 1,544 | > 7,137 |  |
| 100TH                             | -116-9979               | 800           | 0       | 0     | 800     | TUL only                               |
| 2D21 (5727)                       | -552-0082               | 0             | > 296   | 156   | > 452   |  |
| 2E26                              | -188-8569               | 1,227         | 0       | 0     | 1,227   | TV units only                          |
| 217C                              | -615-5604               | 1,744         | 0       | 0     | 1,744   | TUM, TUL only                          |
| 2050 (2050W)                      | -193-5129               | 0             | > 1     | 0     | > 1     | CAL201 only                            |
| 3B25 (T10KV)                      | 5961-00-506-9795        | 1,380         | > 400   | 0     | > 1,780 | T10KV is SSR                           |
| 3B28                              | -108-0252               | 508           | > 750   | 528   | > 1,786 | *Non-procurable* SSR: 1N2637           |
| 4B32 (STR4B32)                    | -188-0944               | 2,454         | 0       | 0     | 2,454   | STR4B32 is SSR                         |
| 4CX250B (7203-4CX250B)            | -892-0828               | 1,566         | 0       | 0     | 1,566   |  |
| 4-65A (8165)                      | -958-9146               | > 444         | 0       | 0     | > 444   |  |
| 4-125A (4D21)                     | -188-0921               | 1,888         | 0       | 0     | 1,888   |  |
| 5R4 (5R4WGB)                      | -681-9741               | 1,671         | 683     | 1,076 | 3,430   |  |
| 5Y3 (5Y3WGA)                      | -262-0218               | 0             | > 1,192 | 927   | > 2,119 |  |
| 5Z3 (?)                           | NO DATA AVAILABLE       | 0             | ?       | ?     | ?       | CA665, 1201 only. *Obsolete* CPL17 EDI |
| 5U4 (5U4GB)                       | -642-8341               | 0             | > 200   | 0     | > 200   | CAL330, 1340 only                      |
| 592                               | -063-1867               | 980           | 0       | 0     | 980     | TU0, TU0-1 only                        |
| 5651 (5651WA)                     | -262-0286               | 0             | 116     | 402   | 518     |  |
| *5654 (5654W)                     | -045-8639               | 333           | 0       | 120   | 453     |  |
| 5670 (5670W)                      | -134-5994               | 0             | 336     | 0     | 336     |  |
| 5686                              | -237-0077               | 493           | 0       | 0     | 493     |  |
| *5725 (5725W)                     | -134-6064               | 0             | 0       | 20    | 20      | FA5258 only                            |



| TUBE TYPE<br>(LATEST DESIGNATION) | CURRENT FSN<br>5960-00- | QUANTITY USED |         |       |         | REMARKS                                  |
|-----------------------------------|-------------------------|---------------|---------|-------|---------|--|
|                                   |                         | PRE<br>CA     | CA      | FA    | TOTAL   |  |
| 5726                              | -879-5078               | 0             | 0       | 80    | 80      | FA5258 only                              |
| 5749 (5749W)                      | -134-5004               | 0             | 0       | 800   | 800     |  |
| 5750/6BE6W                        | -264-3002               | 0             | 0       | 60    | 60      | FA5258 only                              |
| 5751                              | -082-4139               | 0             | 1,176   | 6,444 | 7,620   |  |
| 5763                              | -188-3915               | > 290         | 0       | 0     | > 290   |  |
| 5814A                             | -262-0210               | 783           | 504     | 8,060 | 9,347   |  |
| 5915                              | -262-0223               | 0             | 310     | 228   | 538     |  |
| 6AK5 (5654)                       | -045-8639               | 894           | 0       | 0     | 894     | (See 5654 below)                         |
| 6AL5 (5726)                       | -134-9919               | 0             | 6,688   | 846   | 7,534   | (-879-5078)                              |
| 6AN5 (6AN5WA)                     | -543-0219               | 0             | 0       | 40    | 40      | FA5257 only                              |
| 6AQ5 (6005W)                      | -134-6073               | 0             | 296     | 156   | 452     |  |
| 6AS6 (5725W)                      | -134-6064               | 0             | 628     | 0     | 628     | (See 5725 below)                         |
| 6AS7 (6AS7GA, 6080WC)             | -166-7674               | 0             | 116     | 0     | 116     | CAL485 only. (See 6080 below)            |
| 6AU6 (6AU6WC)                     | -179-3710               | 0             | 11,413  | 1,833 | 13,246  |  |
| 6A3 (4 pin)                       | -617-8615               | 0             | > ?     | 0     | ? ?     | CA665 only. *Non-procurable*             |
| 6B4 (6B4C)                        | -188-3941               | 0             | > ?     | 0     | ? ?     | CAL340, 1402 only                        |
| 6C4 (6C4WA)                       | -557-6780               | 0             | 216     | 306   | 522     |  |
| 6C5 (6C5)                         | -188-8500               | 0             | ?       | 0     | ?       | CA665, 2946 only                         |
| 6F6 (6F6)                         | -188-8504               | 0             | ?       | 0     | ?       | CAL201, 2946 only                        |
| 6H6 (6H6)                         | -188-8499               | 0             | > 38    | >     | > 38    | CAL341, 1396, 1403, 1426, 1486 only      |
| 6J5 (6J5WGT)                      | -228-3765               | 0             | > 650   | 0     | > 650   |  |
| 6L6 (6L6CC)                       | -262-0161               | 0             | 650     | 0     | 650     | Metal Tube; 6L6GT is glass, use shield   |
| 6L7                               | -188-8527               | 0             | > 76    | >     | > 76    | CAL426, 1486 only                        |
| 6N7 (6N7GT)                       | -100-5241               | 0             | 60      | 0     | 60      | CAL349 only                              |
| 6SF5                              | -615-5682               | 0             | ?       | 0     | ?       | Metal Tube; CAL396 only; 6SF5GT is glass |
| 6SH7                              | -989-1251               | 0             | 58      | 0     | 58      | CAL485 only                              |
| 6SJ7 (6SJ7GT)                     | -617-4918               | 0             | > 802   | >     | > 802   |  |
| 6SL7 (6SL7WGT)                    | -188-0883               | 0             | > 78    | 0     | > 78    |  |
| 6SN7 (6SN7GTB)                    | -804-0956               | > 2           | > 2,056 | 0     | > 2,058 |  |
| 6V6                               | -100-5893               | > 136         | > 832   | 528   | > 1,496 | Metal Tube; 6V6GTA is glass              |
| 6X4 (6X4WA)                       | -272-9182               | 0             | 5,056   | 1,030 | 6,086   |  |
| 6X5 (6X5WGT)                      | -188-0926               | 0             | > 60    | 0     | > 60    |  |
| 6Y6 (6Y6GT)                       | -617-6097               | 0             | > 80    | 0     | > 80    |  |
| 6080 (6080WC)                     | -179-3252               | 0             | 168     | 820   | 988     |  |

| TUBE TYPE<br>(LATEST DESIGNATION) | CURRENT FSN<br>5960-00- | PRE<br>CA | QUANTITY USED |       |         | REMARKS                   |
|-----------------------------------|-------------------------|-----------|---------------|-------|---------|---------------------------|
|                                   |                         |           | CA            | FA    | TOTAL   |                           |
| *6136 (6AU6WC)                    | -179-3710               | 0         | 0             | 3,236 | 3,236   |                           |
| 6146 (6146B)                      | -904-9744               | 783       | 0             | 0     | 783     |                           |
| (6146W)                           | -060-6565               | -         | -             | -     | -       |                           |
| *6201 (12AT7WC)                   | -179-4446               | 0         | 0             | 1,700 | 1,700   |                           |
| 805                               | -114-4881               | 0         | 400           | 0     | 0       | CA663,1330 only           |
| 807                               | -114-4868               | 1,580     | 1             | 0     | 1,581   |                           |
| 811A                              | -189-5973               | > 2       | 650           | 528   | > 1,180 |                           |
| 826                               | -617-8540               | 980       | 0             | 0     | 980     | TUO,TUO-1 only            |
| 829                               | -107-8147               | > 1       | 0             | 0     | 1       | TV-2 only                 |
| 836                               | ?                       | 400       | 0             | 0     | 400     | TUL only; SSR CP131 (EDI) |
| 866A                              | SSR:5961-00-850-        | > 4       | > 2           | 0     | > 6     | SSR:1N2637                |
|                                   | 3003                    |           |               |       |         |                           |

NOTES:

1. SSR means solid state replacement.
2. EDI is Electronic Devices, Inc., a manufacturer of solid state replacements for vacuum tubes.

alleviate any problems with the availability of the metal tubes.

In summary, it is concluded that no insurmountable problems presently exist concerning the availability of specific tube types or applicable equivalent replacement components for the VOR equipments.

#### 2.4 Cost Analysis for VOR Tube Requirements

Table 2-5 presents cost data for most tube types used in the VOR equipments. The cost and usage data were obtained from the FAA Depot, General Material Section. Tube types for which no cost data are shown were not included in the demand inquiry made to the supply system computers.

The first two columns in Table 2-5 give tube types and quantities required in the VOR equipments as listed in Table 2-4. Column 3 gives the "CA" or "AC" code which describes supply source and demand velocity as explained in Tables 2-6 and 2-7. The next three columns give the FAA (or DESC) price of the tube in June 1974, June 1976, and the percent increase in the price. The last three columns give average tube usage for the two one-year periods and the percent increase in usage. A negative percent increase represents a positive decrease.

It should be noted that the usage data presented in Table 2-5 is valid only for the tube types stocked and issued exclusively by the FAA Depot to its FAA customers; i.e., tube types whose "AC" codes carry a 1, 3, or 4 in the first position. All other tube types listed are shipped directly to FAA customers by DESC and were not included in the analysis.



TABLE 2-5. COST AND USAGE DATA FOR VOR TUBES

| TUBE TYPE        | QUANTITY<br>REQUIRED<br>(TABLE IV.) | AC | PRICE |       | AVG.      |           | USAGE  |     |
|------------------|-------------------------------------|----|-------|-------|-----------|-----------|--------|-----|
|                  |                                     |    | 6/74  | 6/76  | 6/74-5/75 | 6/75-5/76 | AVG.   |     |
|                  |                                     |    |       | \$†   |           |           |        | \$† |
| HK253            | 400                                 |    |       | 2.80  |           |           |        |     |
| HK454H(250TH)    | 400                                 | 34 | 28.03 | 51.00 | 20        | 23        | 15     |     |
| VR150(VR150-003) | 60                                  | 22 | 3.16  | 1.20  | > 1       | 7         | 600    |     |
| OA2(OA2WA)       | 4,674                               | 23 | .76   | .80   | > 1       | 120       | 11,900 |     |
| OB2(OB2WA)       | > 2,188                             | 23 | 3.00  | 1.03  | 10        | 203       | 1,930  |     |
| OC3W             | 536                                 | 23 | 2.44  | 3.76  | 1         | 6         | 500    |     |
| 1P39             | 40                                  | 22 |       | 1.80  |           |           |        |     |
| 1P40             | ?                                   | 22 |       | 2.10  |           |           |        |     |
| 12AL5            | 1,035                               | 22 | .50   | .64   | 0         | 10        | ∞      |     |
| 12AT7(12AT7WC)   | 3,572                               | 24 | .68   | .88   | 2,806     | 630       | 78     |     |
| 12AU6            | 13,186                              | 22 | .52   | .55   | 6         |           |        |     |
| 12AX7(12AX7WA)   | > 7,137                             | 14 | .40   | .72   | 2,218     | 1,877     | 15     |     |
| 100TH            | 800                                 | 14 | 24.40 | 36.40 | 49        | 66        | 14     |     |
| 2D21(5727)       | 452                                 | 23 | .63   | .99   | 209       | 56        | 73     |     |
| 2E26             | 1,227                               | 23 | 3.19  | 4.14  | > 1       | 49        | 4,800  |     |
| 217C             | 1,744                               | 24 | 25.00 | 52.00 | > 1       | 9         | 800    |     |
| 2050(2050W)      | > 1                                 | 23 | 6.25  | 7.06  | 2         | 12        | 500    |     |
| 3B25(T10KV)      | 1,780                               |    | 4.38  |       |           |           |        |     |
| 3B28             | 1,786                               |    | 4.24  |       |           |           |        |     |
| 4B32(STR4B32)    | 2,454                               | 23 | 6.67  | 8.10  | 289       | 14        | 95     |     |
| 4CX250B          | 1,566                               |    |       |       |           |           |        |     |
| 4-65A(8165)      | > 444                               | 34 | 14.87 | 17.49 | 18        | 718       | 9      |     |
| 4-125A(4D21)     | 1,888                               | 24 | 16.10 | 23.70 | 47        | 49        | 4,800  |     |
| 5R4(5R4WGB)      | 3,430                               | 24 | 36.60 | 37.20 | 2         | 44        | 78     |     |
| 5Y3(5Y3WGTA)     | > 2,119                             | 24 | 6.01  | 8.25  | 37        | 52        | 74     |     |
| 5Z3              | ?                                   | 23 | .40   | 3.10  | 675       | 58        | 5,700  |     |
| 5U4(5U4GB)       | > 200                               | 22 | .53   | .66   | 25        | 11        | 175    |     |
| 592              | 980                                 | 34 | 43.57 | 43.57 | 0         | 117       | 15     |     |
| 5651(5651WA)     | 518                                 | 23 | .64   | .79   | 3         | 97        | 3,133  |     |
| 5654(5654W)      | 453                                 | 34 | .91   | 1.11  | 22        | 7,240     | 20     |     |
| 5670(5670W)      | 336                                 |    |       |       |           |           |        |     |
| 5686             | 493                                 | 23 | 2.36  | 2.26  | - 4       | 23        | 2,200  |     |

| TUBE TYPE             | QUANTITY<br>REQUIRED<br>(TABLE IV.) | AC | PRICE |      |      | AVG.<br>6/74-5/75 | USAGE     |        |
|-----------------------|-------------------------------------|----|-------|------|------|-------------------|-----------|--------|
|                       |                                     |    | 6/74  | 6/75 | 6/75 |                   | 6/75-5/76 | AVG.   |
| 5725 (5725W)          | 20                                  | 14 | .79   | 1.20 | 52   | 1,406             | 1,331     | 5      |
| 5726                  | 80                                  | 14 | .60   | .73  | 22   | 1,815             | 1,454     | 20     |
| 5749 (5749W)          | 800                                 |    |       | .73  |      |                   |           |        |
| 5750/6BE6W            | 60                                  | 23 | .92   | .97  | 5    | 220               | 44        | 80     |
| 5751                  | 7,620                               |    |       | .82  |      |                   |           |        |
| 5763                  | > 290                               | 23 | .86   | .96  | 12   | 687               | 121       | 82     |
| 5814A                 | 9,347                               | 14 | .62   | .74  | 19   | 2,385             | 2,067     | 13     |
| 5915                  | 538                                 | 23 | .85   | 1.23 | 45   | 1                 | 28        | 2,700  |
| 6AK5 (5654)           | 894                                 |    |       |      |      |                   |           |        |
| 6AL5 (5726)           | 7,534                               |    |       |      |      |                   |           |        |
| 6AN5 (6AN5WA)         | 40                                  | 14 | 1.70  | 1.47 | - 14 | 851               | 1,591     | 87     |
| 6AQ5 (6005W)          | 452                                 | 23 | .76   | .88  | 16   | 1                 | 221       | 22,000 |
| 6AS6 (5725W)          | 628                                 |    |       |      |      |                   |           |        |
| 6AS7 (6AS7GA, 6080NC) | 116                                 | 14 | 2.10  | 5.61 | 167  | 943               | 762       | 10     |
| 6AU6 (6AU6WC)         | 13,246                              | 14 | .64   | .78  | 22   | 2,574             | 2,538     | 1      |
| 6A3                   | ?                                   | 72 |       | 1.00 |      |                   |           |        |
| 6B4 (6B4G)            | ?                                   | 22 | 5.80  | 4.23 | - 27 | 0                 | 3         | ∞      |
| 6C4 (6C4WA)           | 522                                 | 23 | .63   | .80  | 27   | > 1               | 46        | 4,500  |
| 6C5 (6C5)             | ?                                   | 22 | 1.29  | 1.29 | 0    | 0                 | 3         | ∞      |
| 6F6 (6F6)             | ?                                   | 23 | 1.10  | 2.18 | 98   | 96                | 17        | 82     |
| 6H6 (6H6)             | 738                                 | 23 | 8.40  | 1.06 | - 87 | 0                 | 22        | ∞      |
| 6T5 (6J5WGT)          | > 650                               | 23 | .80   | 3.63 | 354  | 0                 | 20        | ∞      |
| 6L6 (6L6GC)           | 650                                 |    |       |      |      |                   |           |        |
| 6L7                   | > 76                                | 23 | 1.81  | 2.06 | 14   | 21                | 4         | 81     |
| 6N7 (6N7GT)           | 60                                  |    |       |      |      |                   |           |        |
| 6SF5                  | ?                                   | 72 | .91   | 1.59 | 75   | 11                | 6         | 45     |
| 6SH7                  | 58                                  | 22 | 1.29  | 1.43 | 11   | 0                 | 1         | ∞      |
| 6SJ7 (6SJ7GT)         | > 802                               | 31 | ?     | 2.00 |      |                   |           |        |
| 6SL7 (6SL7WGT)        | > 78                                | 23 | 1.73  | 1.77 | 2    | 0                 | 15        | ∞      |
| 6SN7 (6SN7GTB)        | > 2,058                             | 34 |       | .86  |      |                   |           | ∞      |
| 6V6                   | > 1,496                             | 21 | 1.44  | 1.65 | 15   | 1                 | 14        | 1,300  |

| TUBE TYPE      | QUANTITY<br>REQUIRED<br>(TABLE IV.) | AC | PRICE |       | AVG.      |           | USAGE     |           |
|----------------|-------------------------------------|----|-------|-------|-----------|-----------|-----------|-----------|
|                |                                     |    | 6/74  | 6/76  | 6/74-5/75 | 6/75-5/76 | 6/74-5/75 | 6/75-5/76 |
| 6X4 (6X4WA)    | 6,086                               | 23 | .53   | .50   | 1         | 138       | 13,700    |           |
| 6X5 (6X5WGT)   | > 60                                | 22 |       | 1.64  |           |           |           |           |
| 6Y6 (6Y6GT)    | > 80                                | 22 | .89   | 1.14  | 0         | 3         |           |           |
| 6080 (6080WC)  | 988                                 | 14 |       | 5.61  |           |           |           |           |
| 6136 (62U6WC)  | 3,236                               | 14 |       | .78   |           |           |           |           |
| 6146 (6146B)   | 783                                 | 21 | 2.78  | 3.03  | 10        | 1         | 90        |           |
| or (6146W)     |                                     | 23 | 1.60  | 3.56  | 431       | 96        | 78        |           |
| 6201 (12AT7WC) | 1,700                               | 24 | .68   | .88   | 29        |           |           |           |
| 805            | ?                                   | 14 | 14.50 | 24.30 | 68        | 81        | 12        |           |
| 807            | > 1,581                             | 23 | 3.65  | 4.30  | 18        | 34        | 5,300     |           |
| 811A           | > 1,180                             | 14 | 3.16  | 5.33  | 69        | 783       | 16        |           |
| 826            | 980                                 | 14 | 7.00  | 36.18 | 417       | 57        | 0         |           |
| 829 (829B)     | > 1                                 | 24 | 14.50 | 18.30 | 26        | 61        | 2,950     |           |
| 836            | 400                                 |    |       |       |           |           |           |           |
| 866A           | > 6                                 |    |       |       |           |           |           |           |

Total Quantity: >121,773

TABLE 2-6. EXPLANATIONS OF "AC" COLUMN - FIRST POSITION

- 
- Group 1. Procured wholesale from DESC and shipped to the Depot for technical evaluation prior to placement in depot stock; issued to customers from Depot Warehouse.
- Group 2. DESC direct ship to field facilities, but stocked in Depot warehouse for issue to FAA shops. Stock levels based on local demand/consumption only.
- Group 3. Commercially procured by Depot; stocked and shipped from warehouse.
- Group 4. Commercially procured by Depot; stocked and shipped from warehouse.
- Group 6. Exchange and Repair item.
- Group 72. DESC direct ship to all customers, including FAA shops.\*
- 

\* "7" identifies planned direct ship. The second position (2) identifies supply source (DSA) rather than demand dollar velocity.

- 71 = GSA Direct Ship  
72 = DSA Direct Ship  
73 = Commercial Direct Ship.



TABLE 2-7. EXPLANATION OF "AC" COLUMN - SECOND POSITION

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Group 1. New Items. In system under three years from date of first receipt, with less than three average annual demand transactions per year.

Group 2. Low Value/Velocity Demand Items. In system three years or more from date of first receipt and/or with three or more average annual demand transactions, and the forecasted demand value is less than \$250.00.

Group 3. Intermediate Value/Velocity Demand Items. In system three years or more from date of first receipt and/or with three or more average annual demand transactions, and forecasted demand value ranges from \$250.00 through \$5,000.000.

Group 4. High Value/Velocity Demand Items. In system three years or more from date of first receipt and/or with three or more average annual demand transactions, and the forecasted demand value exceeds \$5,000.000.

Group 5. Slow Moving Items. In system three years or more from date of first receipt with at least one, but less than three average annual demand transactions.

Group 0. Items With Less Than One Demand Transaction Per Year. In system three years or more from date of first receipt with less than one demand transaction per year.

Group 6. Insurance Items. Items for which a requirement is not normally expected, its need usually being caused by unpredictable events; the item is essential; and the lead time required to obtain the item when needed would create an unacceptable situation such as a stoppage of essential operations or existence of a condition hazardous to human life.

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It is further noted that the valid usage data in Table 2-5 includes usage by all equipments in the FAA Inventory and not just the VOR equipments. Consequently, no tube replacement rate can be determined according to

$$\text{Replacement Rate} = \frac{\text{Normal Usage}}{\text{Total Quantity Required}} \times 100\% \quad (2-1)$$

because the total quantity required of any given tube type is not presently known. This observation leads to the important conclusion that the calculation of a tube replacement rate requires either:

- (1) Knowledge of the total tube usage and total equipment tube requirements; or
- (2) Knowledge of the tube usage for just the VOR equipments and the total VOR tube requirements.

The tube replacement rate is important in estimating the cost of replacing tubes in the VOR equipments (and eventually in other tube-type equipments). Due to lack of information, replacement rates will have to be estimated and the corresponding costs computed based on a known rate of price increase. For example, consider the HK454H(250TH) tube in Table 2-5. Assume a 10% replacement rate per year; i.e.,  $.10 \times 400 = 40$  tubes required per year. Based on a 35% per year price increase, the following costs are found:

| <u>Year</u> | <u>Cost/Tube</u> | <u>Annual Tube Cost</u> |
|-------------|------------------|-------------------------|
| 1974        | 28.03            | \$ 1,121.20             |
| 1975        | 37.84            | 1,513.62                |
| 1976        | 51.00            | 2,040.00                |
| .           | .                | .                       |
| .           | .                | .                       |
| .           | .                | .                       |
| 1986        | 1,024.03         | 40,961.11               |



Of course, a constant 35% per year price increase may or may not be realistic.

The data in Table 2-5 may be used to estimate a more accurate annual increase in tube price as averaged over the tube types. The total quantity of tubes required by the VOR equipments is >121,773 and includes 76 different tube types. The total quantity of tubes for which 6/74 price information is available is 100,809; the total worth of these tubes in 6/74 was \$338,984. The average tube worth was \$3.36. The total quantity of tubes for which 6/76 price information is available is 121,425; the total worth of these tubes in 6/76 was \$503,406. The average tube worth at this time was accordingly \$4.15. Assuming a constant annual percent increase in tube price for the two-year period, the annual price increase is computed according to

$$(6/74 \text{ Price})(1 + x)^2 = (6/76 \text{ Price}) \quad (2-2)$$

to be 11.1% per year (approximately equal to the inflation rate for these two years!).

When only those tubes for which 6/74 price information is available are used in the 6/76 calculations, there results a total worth of \$466,392 for the 100,809 tubes. The average tube worth in this case is \$4.63. This figure translates to a price increase of 17.4% per year.

A third estimate of tube price increase may be obtained by averaging tube worth over only those types which are used in the smaller quantities in the VOR equipments. When those types for which the quantity required is less than 1000 are considered, there results 12,819 tubes in this category for which 6/74 price information is available. The total worth

of these tubes in 6/74 was \$103,742 and \$153,225 in 6/76. The average tube worth was \$8.09 in 6/74 and \$11.95 in 6/76. These figures translate to a price increase of 21.6% per year for these tube types.

If one uses the 17.4% per year tube price increase and assumes a 10% tube replacement rate for the VOR equipments, then the tube replacement costs are found as presented in Table 2-8. It is expected that these costs are miniscule compared to the costs of replacing entire VOR equipments.

The figures presented in Table 2-8 must be considered as estimates only. Other factors could cause drastic increases or decreases in tube prices and/or replacement rates which would alter these figures considerably.

## 2.5 FAA Tube/Equipment Lists

Tables 2-9 and 2-10 are excerpts from Volume II of this report which epitomize the correlations in that volume of tube types with FAA equipment, and vice versa. The data presented in Volume II are based on original data provided by the FAA Depot.

Table 2-9 is a sample of the listing which lists tube types in alphanumerical order, shows the FAA equipments in which each tube type is used, and shows the quantity of the tube required. Equipments are separated according to the FAA type designation: FA, CA, and other (e.g., TBC, TV-1, etc.). The complete listing consists of 156 pages of over 8,000 entries. The primary use of the list is to identify specific pieces of equipment which may be affected by a shortage of a particular tube type.

Table 2-10 is an excerpt from Volume II which lists FAA equipment in alphanumerical order. For each equipment type, the tube types required

TABLE 2-8. ESTIMATED TUBE REPLACEMENT COSTS FOR VOR EQUIPMENTS.

| YEAR            | ANNUAL REPLACEMENT COSTS* |
|-----------------|---------------------------|
| 1976            | \$ 50,341                 |
| 1977            | 59,100                    |
| 1978            | 69,384                    |
| 1979            | 81,457                    |
| 1980            | 95,630                    |
| 1981            | 112,270                   |
| 1982            | 131,805                   |
| 1983            | 154,739                   |
| 1984            | 181,663                   |
| Total (8 years) | \$936,389                 |

\* Assumes 17.4% per year price increase and 10% tube replacement rate.

Table 2-9. Tube List Excerpt from Volume II.

| EQUIPMENT | TUBE TYPES (NUMBER USED SHOWN IN PARENTHESES)   |   |  |  |  |  |
|-----------|---|---|--|--|--|--|
| FA-7233J  | 6AS6W ( )<br>5814A (02)<br>5687WA (07)  | 5725 (02)<br>6AU6 (01)  | 12AU7 (01)<br>5965 (01)  |  |  |  |
| FA-7233E  | 6AS6W ( )<br>5814A (03)   | 5725 (01)<br>5725 (01)  | 5687WA (05)<br>5687 (02)   |  |  |  |
| FA-7234   | 5651WA (01)<br>6AS7GA (06)  | 12AX7 (01)<br>6AU6 (02)   | 6A2WA (01)   |  |  |  |
| FA-7234A  | 12AX7 (01)<br>6AU6 (02)   | 5651WA (01)   | 6AS7GA (06)  |  |  |  |
| FA-7243   | 5814A (03)<br>12AU7 (01)  | 5965 (23)   | 7044 (24)  |  |  |  |
| FA-7244   | 5965 (36)   | 7044 (02)   |  |  |  |  |
| FA-7246   | 12AX7 (03)<br>6336A (05)  | 5651 (01)<br>6AU6 (02)  | 5763 (03)  |  |  |  |
| FA-7251   | 6AS6W ( )<br>5965 (26)  | 5725 (01)   | 7044 (04)  |  |  |  |
| FA-7252   | 6AU6 (02)<br>6X4 (01)   | 12AX7 (01)<br>5651 (01)   | 5R4GY (02)<br>6AS7G (03)   |  |  |  |
| FA-7260   | 840214 (02)   |   |  |  |  |  |
| FA-7262   | 840214 (01)   |   |  |  |  |  |
| FA-7271   | 604 (02)<br>1V2 (02)<br>12AT7WA (09)<br>6AH6WA (02)<br>5687WA (09)<br>68Q5 (02)<br>7308 (03)<br>12BY7A (02) | 0B2WA (02)<br>5814A (19)<br>6U8A (06)<br>6080WA (03)<br>2B22 (02)<br>5726 (01)<br>2C36 (01) | 6J6WA (01)<br>6AL5W ( )<br>5651WA (03)<br>6216 (03)<br>6AU6WA (03)<br>4MP1 (01)<br>7754 (01) |  |  |  |
| FA-7272   | 6AU6WA (03)<br>0B2WA (02)<br>12AT7WA (09)<br>1V2 (02)<br>5687WA (09)  | 604 (02)<br>2C36 (01)<br>5726 (01)<br>5814A (19)<br>6AL5W ( )                               | 6J6WA (01)<br>6U8A (06)<br>6AH6WA (02)<br>6080WA (03)<br>6216 (03)                           |  |  |  |



Table 2-10. Equipment List Excerpt from Volume II.

| TUBE TYPE | FA EQUIP-NO.USED  | CA EQUIP-NO.USED                         | OTHER----NO.USED  |
|-----------|---|--|---|
| 12AX7     | FA5450 01<br>FA5452 01<br>FA5465 01<br>FA5524 01<br>FA5585 01<br>FA5587 04<br>FA5587A 04<br>FA5587A-3 04<br>FA6120 02<br>FA8176 01<br>FA8177 01                                 |  | TV-25 01<br>TV-26 01<br>TV-30 01<br>TY-6 01<br>MD141GR 01<br>MD-129A-GR 02<br>RV-12B 01<br>R-278A-GR 02<br>R-361GR 02<br><br>TM4 01<br>TM-8 01<br>TV-24 01<br>TV-6 01<br>T282-GR 01<br>T-217A-GR 02 |
| 12AX7A    | FA-5394 02<br>FA-5394/1 01<br>FA-5394/2 01<br>FA-5395 03<br>FA-5395/2 03<br>FA-5525 01<br>FA-5525/1 01<br>FA-5629/1 01<br>FA-5642/1 01<br>FA5394 03<br>FA5395 03<br>FA5395-2 03 |  | TRV-5 01<br>TRV-6 01  |
| 12AX7WA   | FA-5257 01<br>FA-5430 01<br>FA7805 10<br>FA7808 02  |  |   |
| 12AY7     | FA5207 23   | CA-1560 01<br>CA-1630 01                 | T-217A-GR 01  |
| 12A6      |   |  | BC624C 01   |
| 12A6Y     |   |  | BC733D1 01  |
| 12A7A     |   |  | RTN-2 VOL3 01   |
| 12BH7     | FA-5477 01<br>FA-5496 01<br>FA-5596 01<br>FA6120 01   | CA-1691 01                               | RML-4 01  |
| 12BH7A    | FA-7177 02  | CA-4460 01                               |   |
| 12BY7     | FA-6842 02<br>FA-6842A 02<br>FA-6847 02<br>FA-6847/A 02<br>FA-6847A 02  |  |   |
| 12BY7A    | FA-7122 02<br>FA-7271 02<br>FA-7272 02<br>FA-7274 02  | CA-1755 02<br>CA-1755A 01<br>CA-1755B 02 | TRV-3 01<br>TRV-5 01<br>TRV-6 01  |
| 12B4A     | FA-6286 12  | CA-4610 12                               | RTC-1 12<br>RTN-2 VOL3 12   |
| 12C8      |   |  | BC624C 01   |
| 12DP7C    | FA7805 01   |  |   |

are shown. Quantities required are shown in parentheses. Note that all equipment types are left justified so that the left-most number in the designation determines greatly the alphanumerical order; e.g., CA750 appears later in the list than CA2320 since  $7 > 2$ . The primary use of the equipment list is to identify all tube types in a particular piece of equipment. The complete list consists of over 100 pages.

The tube/equipment lists in Volume II represent a culmination of efforts to provide a data base which can be used in making rational decisions concerning the replacement of tube-type equipment when tube shortages occur.

## CHAPTER 3

### SOLID STATE REPLACEMENTS

Considerable advertising has been done by the proponents of solid state devices offered as replacements for scarce or non-procurable vacuum tubes. From an application standpoint the replacement problem can be divided into four areas:

1. Power rectifiers
2. Voltage regulators and reference devices
3. Low current signal diodes
4. Amplifiers/oscillators

The problems involved in each area are discussed below.

#### Power Rectifiers

It is in this area that numerous manufacturers are offering direct plug in replacements for high voltage tube type rectifiers. References 1 and 2 are representative catalog listings showing the wide variety available. However, the terminology 'direct replacement' must be examined in some detail. While silicon rectifiers with voltage and current capabilities equal to commonly used high vacuum and gaseous rectifiers are widely available and easily packaged to conform to tube configuration, significant and inherent differences must be considered. First, the forward drop is less. The drop per junction is approximately 1 volt. Gaseous rectifiers such as the type 83 and 872 have a peak voltage drop of 10 volts (approximately) Reference 3. On the other hand the more commonly used high vacuum rectifiers will show a voltage change of up to 60 volts from half to full load (5U4G, capacitor input filter). Thus, plugging a direct silicon replacement into a circuit

calling for a 5U4G can cause significant over voltages. This can be compensated for by the use of dropping resistors, but, it must be done on a case by case basis, examining each circuit for load and type of filtering, selecting the resistance to provide the proper drop at the operating load. The FAA Aeronautical Center is well abreast of the situation. Solid state replacements for gaseous tubes such as the 4B32 and 872 are now routinely supplied to the field. Appropriate modification instructions with plug in replacements are also being furnished for installations using types such as the 5Y3G, 5Z3G, 5R4G, and 5U4G.

The silicon rectifier is an instant on device, supplying output voltage immediately upon turn on. Voltage applied to the plates of non conducting tubes in the equipment can, over a period of time, degrade the tubes by stripping the oxide coating of the cathode. For this reason many circuits employ rectifiers with indirectly heated cathodes such as the 6X4, 6X5 so that the rectifier cathode heats at the same rate as the others in the circuit. Here again installation of protective circuitry would be necessary. Simple time delay devices such as thermal relays can provide protection. However, again on a case by case analysis of the equipment circuit involved.

It should also be noted that ratings must not be exceeded. Solid state devices are unforgiving. Overloads, even transients can result in catastrophic failure whereas tube devices generally will sustain severe overloads, perhaps degrading but still operational. The 872 with a nominal current rating of 1.25 amperes average and 5 amperes peak will sustain a 'fault' maximum of 50 amperes maximum for duration of 0.2 seconds maximum. Reference 3.

#### Voltage Regulators and Reference Devices

The zener diode would appear to be a logical candidate for replacing tubes in the OA, OB, OC, and VR series. They are made in a wide power capacity range and voltage steps. However, again serious constraints must



be imposed. First, the zener is an excellent noise source. In the 100-150 volt range the zener operates in the avalanche mode. (Avalanche diodes are commonly used in commercially available noise generators.) Furthermore, if used in an RF environment such as a radar, stray pulsed energy picked up by adjacent circuits can be rectified and superimposed on the regulated line.

#### Low Current Signal Diodes

Low current signal diodes such as the 6AL5/12AL5 and more obsolete 6H6/12H6 families are commonly used in detector, discriminator, AGC circuits and the like. In most applications these tubes can be readily replaced by silicon diodes. A commercially available plug in unit to replace the 6AL5 is available. However, again interchangeability across the spectrum of use must be examined on a circuit by circuit basis. In most cases the simplest approach is to directly wire the diodes across existing tube socket pins, selecting appropriate diodes for the circuit involved.

#### Multielement Tubes

Solid state plug in replacements for specific triodes and pentodes have been in a mass production for approximately four years. References 4, 5, 6, and 7. Junction Field Effect devices have been used singly or in cascade arrangement to approximate both pentodes and triodes. However, in practice production units are circuit sensitive. Thus where a non-selected vacuum tube will fill the replacement requirements for all but extreme applications, these devices must be tailored to fit each specific case. For example, one manufacturer specifies as many as six different types to replace a single vacuum tube such as the 6AK5,<sup>(8)</sup> depending on the circuit application. On the other hand the same FET devices performing a specified circuit function may serve as a substitute for more than one type of tube. In simple terms it is safe to say that solid state devices with tube designations such as 6AK5( ) 12AT7( ) etc. can not be considered as generalized, across the board plug in replacements. In practice each different circuit in which a particular vacuum tube is used, would have to be analyzed and the solid state replacement selected to fit - if possible. The U.S. Navy has used this approach in a study to determine the feasibility of extending the useable life of the AN/APA-125 Indicator. Reference 9. This is a general purpose unit used to display range and bearing information from the AN/APS-80 radar. The overall study involved several other problems inherent in the indicator not relevant to this report. Fifty-nine of the indicator's eighty-nine tubes were replaced with

no adverse effect on operation and a net improvement in power consumption/heat dissipation problems. However, no data was made available as to the number and types of different circuits affected or the number of FET types versus number of tube types replaced, certainly a factor in the economics of supply. The Navy's final conclusions and recommendations have not yet been made available. The data presented did demonstrate that substitutes in selected circuits are possible. However, there was insufficient data on which to base any economic advantages. This would have to be based on equipment socket by socket analysis. Tests have also been performed by the FAA Aeronautical Center, Reference 10, which indicates unsuitability in front end, oscillator and IF applications. On the other hand, units tailored to telephone company specifications are widely used to replace vacuum tubes used at audio frequencies in line amplifiers and other terminal equipment. Reference 5. New developments should extend the frequency range of the device and it is anticipated that power capability will be increased from the current 3.5 watts (approximately) to 10 watts. Reference 9.

### Cathode Ray Tube Replacements

Should the cathode ray tube become unavailable, undesirable, or excessively expensive, the most logical and practical possibility for replacement is the A-C plasma display panel. Such panels are now economically competitive with color cathode ray tubes and have some advantages for single color applications.

The panel consists of two quarter-inch plate-glass substrates--each having parallel conductive electrodes applied to one surface. A thin layer of transparent dielectric material is placed over the electrodes, leaving their ends bare to allow connection to the control/drive circuitry. The two glass substrates are sealed together to form the grid of the display matrix and a neon-based gas mixture fills the space between the sealed substrates. The completed panel is just one-half inch thick, with height and width dependent upon the number of electrodes in each axis.

The display panel is operated through a periodic alternating SUSTAINER waveform which is supplied continuously to all vertical and horizontal electrodes. The amplitude of the sustainer is adjusted to a level that is not sufficiently high to cause ionization of the gas. By superimposing an appropriately timed ADDRESS PULSE on top of the sustainer on one electrode in each axis, a discharge is established at the point where the electrodes intersect.

As the discharge occurs, a charge with a polarity opposite to that of the sustainer is formed at the surface of the dielectric in the vicinity of the discharge. This is referred to as WALL CHARGE, and is basic to the display's retention of information, or MEMORY. As the discharge extinguishes and the sustainer reverses, the wall charge remains and adds to the reversed



sustainer. The net potential across the gas again exceeds the breakdown voltage of the gas and another discharge is started. The discharge sequence repeats during each sustainer half-cycle at a frequency high enough to appear continuous to the eye.

Individual discharges can be turned off by again superimposing an address pulse on top of the sustainer. This is done at a time in the sustainer cycle so that the wall charge is reduced to a level that, when added to the reversed sustainer, is insufficient to cause the continuation of the discharge sequence.

A. C. plasma display technology provides an uncommonly effective link between man and high-speed computer systems. These units with resolution of up to 60 dots per inch are now commercially available and display both alphanumeric and graphic information accurately and without distortion or variation in intensity to allow more efficient use of computer-based systems. The units feature inherent memory, i.e., no refresh of static data required, and eliminate the need for remotely located support materials.

These panels represent a total departure from conventional CRT technology. X-Ray emissions and implosion hazards are non-existent. And unlike CRT assemblies, there are no parts subject to misalignment or sensitive to harsh environments.



## CHAPTER 4

### CONCLUSIONS AND RECOMMENDATIONS

In our efforts to assess the availability of vacuum tubes through the 1980 time frame, we have found hard factual information difficult to obtain. Therefore, these conclusions and recommendations are based on the most informed sources available. These sources include the remaining major U.S. tube manufacturers, field personnel, Defense Electronic Supply Center (DESC), FAA Depot, Defense Logistics Agency and DOD Product Engineering Service Office (PESO).

In our discussions with the three remaining tube manufacturers in the United States, i.e., Amperex, General Electric and Sylvania, we have found a common thread of optimism. Management of these companies made statements to the effect that "we will be the last company to go out of the tube manufacturing business and we foresee no problems within the next five years." One must remember that the people making these statements have little or no control over the phase-out dates of their operations. Clearly, when the operation becomes nonprofitable, upper management in the company will phase it out. Any planned or projected phase-out dates are classified company confidential due to the effects on worker morale, marketing and competitive pricing. It was noted at one plant that the average years of service of the workers was 27 years with no training program in being. This appears as a subtle indication that the future of the operation is questionable. Fortunately, competition still exists in the tube market.

There is some evidence that many retail dealers are stocking fairly large numbers of vacuum tubes and they will assure everyone that no problems will occur. This is in fact merely a form of advertising to assure eventual depletion of their inventories. It is true, however, that such sources may temporarily alleviate problems. Obviously, their tubes are manufactured by the three existing U.S. manufacturers or overseas locations. There appears to be an adequate supply of tubes if one is willing to accept overseas sources.

As to the quality of tubes, we have found isolated complaints of poor quality tubes from field personnel. Conversely, we have heard as many complaints from suppliers that tubes meeting specification requirements were being returned as unuseable. There is insufficient evidence that these kinds of complaints are new or are relevant to the diminishing source of supply problem.

It is fairly clear that the cost of tubes will increase as the original equipment manufacturers (OEM) market decreases. The price will undoubtedly be related to the available market and to the existence of both U.S. and overseas competition.

We have found no indication of shortages or serious problems in the special purpose tube types such as large transmitting, microwave and cathode ray tubes. There are still a number of manufacturers in this area and the market is strong and competitive. The declining consumer entertainment market has had little effect on the availability of these tube types.

With regard to the types of tubes described in the introduction of this report, we see no course of action other than a close, continuous monitoring of the situation. We expect that isolated problems will occur, but there is no generic solution to such problems. An "isolated" tube problem can, of course, have an impact that ranges from trivial to extreme. The most sensible approach is to solve the problems as they occur since each may well have its own unique solution ranging from temporary subsidization, direct overseas purchase, to equipment modification. An example is the recent bulletin from DESC indicating that commercial tubes will be supplied for certain MIL-SPEC tubes type until a new source for the MIL-SPEC tubes can be established. (See Appendix B). At this time, there appears to be no justification for the deliberate equipment phase out because of tube supply problems. However, it would be advisable to phase-out pre- World War II equipment.

### Comments on Solid State Replacement

The bulk of the vacuum tube replacement requirements fall into the rectifier and amplifier oscillator categories. As noted, in the case of rectifiers, FAA depots are already shipping solid state replacements and modification instructions.

Consideration should be given to expanding the use of solid state replacements in this area. Commercially, the type 866 is being replaced by the 1N2637 and the type 83 by the 1N2634. A number of solid state replacements are routinely used in television CRT anode supplies. In each case, the substitution should be depot checked for suitability.

Because of the peripheral effects, use of zeners as general replacement for voltage regulators and reference voltage tubes does not appear economically feasible. Problems of shielding and noise filtering would require extensive circuit modification.

Replacement of signal diodes such as the 6AL5 and 6H6 in clipper, clamping and low level rectification circuits in VOR equipments should be considered as a logical follow on to replacement of the power rectifiers. A "direct" plug in replacement for the 6AL5 designated TR 1002 is offered by Teledyne Semiconductor, Mountain View, California. However, again, its circuit suitability should be verified on a case by case basis.

The least promising area for replacement is that of multi-element tubes, triodes, tetrodes, and pentodes. At first glance, JFET technology would appear to offer a capability without requiring major circuit modifications. However, in practice, the devices are extremely circuit sensitive and must be tailored to meet the application. In addition, frequency and power limitations are still problems. Thus, while the devices are apparently economically feasible in mass audio applications such as in telephone line amplifiers and repeaters, applicability to the circuitry found in FAA equipments must still be based on detailed analysis of each socket circuit.

Application of solid state replacements for vacuum tubes is well under-  
way in the area of power rectifiers, the area of voltage references and  
regulators does not look promising, further investigation is advisable in  
the small signal diode area and in the replacement of multi-element tubes  
in other circuitry is advisable.



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## APPENDIX A

This appendix consists of data extracted from the DOD AD HOC Vacuum Tube Support Group Final Report dated June 1975 which appear pertinent to the FAA VOR Vacuum Tube Availability Assessment Problem. Persons desiring a broader scope of information should refer to the above report.

### Purpose

The DoD Ad Hoc Vacuum Tube Support Group (DVTSG) was established to:

- (a) identify specific tubes presently out of production and/or in short supply, as well as those anticipated to be in this position in the future;
- (b) determine equipment applications, projected equipment life, and rate of tube replacement;
- (c) develop practical and economical alternatives to the worsening problem of diminishing production sources for needed replacement tubes.

### Findings

- 1. Allegations concerning the impact of the lack of manufacturing sources for vacuum tubes and the inability to take prompt and appropriate actions are essentially true.
- 2. No single technical solution exists for ameliorating the problem of diminishing sources for vacuum tubes.

3. There is no governing procedure for gathering the data needed to determine appropriate action.
4. There is no management requirement for determining the remaining inventory life of end article applications for most receiving tubes.
5. Prompt identification of end article application and forecasted remaining life of equipment furnished in accordance with international FAA security agreements is not currently practicable.
6. A central file to contain end item application data for all consumable items is not feasible at this time. File space and procedures may permit construction and maintenance of a file of selected items.

#### Recommendations

Recommendations 1-4 are short term actions, the remainder are long term continuing efforts.

1. Issue a DoD Directive specifying the responsibilities of affected DoD Components.
2. Issue a joint DSA/Military Departments implementing document to institute improved procedures for addressing each lack of manufacturing source problem for consumable items.
3. Generate a temporary Code to prevent disposal of needed consumable items. Subsequently, create a separate code symbol compatible with the definition of the problem of lack of manufacturing source.
4. Convene a joint OSD/DSA/Military Department Group to guide actions necessary to include improved practices into forthcoming automated materiel management procedures.

5. Develop and institute procedures for last buy funding and guidelines for requesting funds to subsidize or otherwise support COCO, GOCO, or GOGO consumable item production facilities.
6. If justified by an economic analysis, create an end item application file for selected consumable items and institute procedures for maintaining it.
7. Integrate improved procedures for dealing with problems of no manufacturing source into future automated materiel management process.

#### Background

Vacuum tube technology, now almost three quarters of a century old, has been supplanted by the ubiquitous semi-conductor and integrated circuit technology. Yet, the Department of Defense and the Civil Agencies of Government have a large inventory of tube powered equipment which will still operate satisfactorily as long as replacement tubes are available. Funds for modernizing or replacing all this equipment are unlikely to become available in the foreseeable future in this period of severe budget austerity. With the disappearance of the market for tubes for the original equipment manufacturer (OEM), the replacement market itself is insufficient to support profitably all of the vacuum tube manufacturing companies. Of the approximately two dozen major tube manufacturers which existed twenty years ago, no more than a half dozen survive today. This problem is particularly acute in the area of receiving tubes.

#### Study Objectives

The DVTSG was established to identify the magnitude and impact on military capability of the diminishing production source problem. The



initial plan was to conduct a survey to identify the specific tubes out of production permanently or likely to be in the near future and to determine the end item equipment application. It was expected that a pattern would emerge which would lead to the development of recommendations for practical and economical actions.

As the group gained insight into the nature of the overall problem, it became evident that the original plan was not likely to yield the desired results. The resultant actions undertaken by the DVTSG as the underlying problems became more evident and appear later in this appendix.

#### Situation within DoD

##### 1. Receiving tubes not readily identifiable in Federal Stock Class 5960

It was evident that the conduct of a meaningful survey would be impossible without some clear definitions of terms. Some considered the terms "vacuum tube," "electron tube," and "receiving tube" to be synonymous. Others disagreed. The DVTSG eventually settled on the term "receiving tube" and accepted the definition which included those negative grid electron tubes whose anode dissipation did not exceed 50 watts, and low power rectifier tubes (under 250 watts). This definition covered the vast majority of tubes that were the products of the "receiving tube" industry.

As the DVTSG examined published listings of electron tubes which had previously been declared "non-procurable," it became evident that the lists contained more than just receiving tubes. Further investigation disclosed that previous recommendations to sub-classify Federal Stock Class (FSC) 5960, Electron Tubes, with additional descriptors such as receiving tube, klystron, magnetron, transmitting tube, etc. had been rejected. Thus, the listings

included not only those tubes which were products of the declining receiving tube industry but also those that the last manufacturing source had discontinued production for any one of a number of possible reasons, not necessarily related to the plight of the receiving tube industry. FSC 5960 also contains tube related hardware items.

## 2. No central file on end article application

The Military Departments differ significantly in their approach to materiel management. Their responses reflected these differences. It was evident that, whatever the intent of the materiel management philosophy used by a Military Department, none could rapidly respond to a request for comprehensive current application data. Nor could they promptly provide a life cycle forecast for all equipment applications that were identified. This is not to say that no data existed. Responses ranged from literally no answer to extensive lists of application data. A similar situation existed for requests for forecasts of the expected remaining life of end article equipment applications. In those instances where files had been created, they were not all inclusive and often had not been subsequently maintained. Thus, end item application data files, when available, were fragmented, incomplete and out of date.

## 3. Reutilization philosophy inappropriate

There were repeated allegations of needed tubes being furnished by surplus dealers whose stock had originally been purchased from government surplus disposal operations. This was due to a number of reasons. First, the value of excess tubes, carried at the procurement cost rather than replacement cost, was generally below the threshold (\$300) for reporting back to the consumable item manager. Often tubes would be part of a miscellaneous lot of materiel declared excess. If not identified as Class A

condition (unused, in original marked container) the tubes were not reported to the inventory manager.

Other anomalies exist. For example, if usable surplus stock is offered to an integrated manager, it is likely to be refused if a six-year stock is on hand. Yet, the last buy program is proceeding on the basis of acquiring a ten-year stock.

#### 4. Uncertain coordination

The interests of the materiel management and supporting elements was not always in consonance with the requisitioners' interests. Forecasts of impending stock outs are transmitted to Headquarters elements in the Military Departments, not the requisitioning activities. Later, actual stock-outs resulted in cancelled requisitions, which were returned to the requisitioning activities. Headquarters elements were not notified. Thus, within the Military Departments the degree of coordination of the information furnished by DESC is dependent upon the procedures which the Departments had instituted. In most instances, those coordination procedures were informal at best. The resulting information exchange, therefore, was uncertain.

#### 5. Lack of credibility

Through a variety of means, the Defense Electronic Supply Center (DESC) had attempted to alert its customers of any forthcoming problem resulting from diminishing production sources. This had not always proved helpful. For example, customers would be notified that a tube is or was expected to be "non procurable." The customer and/or the engineering support activity would respond by providing DESC with the names of distributors, surplus dealers, jobbers and other secondary sources of tubes. Often DESC already



knew these sources and also knew that the lineage, age, life, and quality of such stock was suspect. The confusion was compounded because many did not realize that the term "non procurable" was intended to mean "not currently available from a manufacturing source." A tube declared "non procurable" might still be available in limited quantities from non-manufacturing sources.

Personnel in the Military Departments became increasingly skeptical. They did not believe the seriousness of the impending tube shortage problems. One spokesman constantly referred to it as an "alleged" problem. Previous declarations by the Defense Electronic Supply Center that certain tubes had, or would soon, become unavailable had rarely resulted in actual stock outs. The DESC usually took whatever extraordinary action was necessary to obtain an adequate supply from returns and non-manufacturing sources. Although successful from a mission effectiveness point of view, these activities which were carried out after a declaration of likely inability to satisfy future requisitions, impaired DESC's credibility with its customers. As these non-manufacturing sources are depleted, the problem becomes more acute. Despite the increasing urgency of the situation, effective action was often stymied by this increasing skepticism.

### Industry

#### 1. Lost Economy of Scale

The Chairman and Technical Advisor of the DVTSG visited manufacturing facilities of three major receiving tube producers to verify information presented. They found that the economies of scale resulting from a mass market were being lost. Tube prices were escalating rapidly because certain irreducible fixed costs had to be spread over a rapidly declining sales quantity.



## 2. Parts Availability

Contractors also suffered parts availability problems. In some cases, only a single supplier remained to furnish vitally needed components. In other cases, offshore sources had to be utilized when domestic sources no longer existed. Subcontractors to the tube industry also suffered from the same rapid escalation in costs as their sales volume diminished in relation to the fixed costs of operation. Yet, despite the rapid price escalation, few in the industry report adequate profits, if any at all.

## 3. Industry Consolidation

Each member of the industry is attempting to consolidate in order to continue to survive. Plants are being shut down, equipment moved or sold, employees furloughed. One plant had a factory work force that averaged 28 years of company service and no factory employee with less than 17 years of company service. All less senior employees had been laid off previously. Also, each of the major tube manufacturers is an operating division of a corporate conglomerate. The decision as to the continued existence of these, marginally profitable tube manufacturing operations emanates from corporate headquarters. Many expressed concern that operations which do not meet corporate standards of profitability would be closed. Also, the retirement of certain individuals means that needed critical skills are being lost with little hope of training any youthful replacements.

## 4. Proprietary Planning

Industry disarray is aggravated even further by the lack of coordinated planning. "Long range" planning is considered proprietary information because of the marketing advantages a competitor would have if he knew another's

future intentions. Therefore, there is little advance notice of any significant action that would erode one manufacturer's remaining market to the benefit of another. Any joint actions undertaken by competitors would likely be in violation of the Anti-Trust Statutes.

#### Actions

##### Identify DESC Managed Receiving Tubes

An analysis of Federal Stock Class (FSC) 5960, Electron Tubes was undertaken. Management records indicated that the Defense Electronic Supply Center (DESC) managed 6,724 National Stock Numbers in FSC 5960. Of these 4,045 were classified as "electron tubes." Because of the lack of sub-classification, the DESC managed population of receiving tubes had to be identified manually. This was accomplished by knowledgeable specialists who could classify tubes either by their personal familiarity or the use of Electronic Industry Association (EIA) type coding and associated published tube characteristic information. The number of DESC managed receiving tubes was eventually fixed at 941 (Figure 1).

| <u>REGISTERED TO</u> | <u>NUMBER OF TYPES</u> |
|----------------------|------------------------|
| ARMY                 | 701                    |
| NAVY                 | 773                    |
| USAF                 | 857                    |
| USMC                 | 369                    |
| FAA                  | 650                    |
| OTHER                | 839 (6 NO DOD)*        |
| DESC MANAGED         | 941**                  |
| OTHER MANAGED        | 142***                 |

\* AS OF 6 APRIL 1974

\*\* AS OF 6 MAY 1974

\*\*\* AS OF 30 MAY 1974

FIGURE 1

### Verify "Non-Procutable" List

The original group of 136 "non-procutable" receiving tubes was examined. Many of the tubes originally identified as "non-procutable" had to be reclassified due to Sylvania's willingness to undertake one last consolidated run of all needed "Loctal" type tubes. "Loctal" type tubes represented about half of the total types of "non-procutable" receiving tubes. ("Loctal" tubes are those that lock into their socket. The design was said to have originated for use in early automobile radios. Sylvania is the sole supplier).

Other tubes also had to be reclassified due to the willingness of a small west coast manufacturer to undertake ~~the~~ production of limited quantities of selected tubes. Whereas, a volume manufacturer might expect upwards of 3,000 tubes per shift from each production line, this supplier's total plant capacity is estimated at 2,000 tubes per month.

The situation was further clouded by additions and deletions as preferred versions of a family of tubes changed with availability in the secondary market or government-owned shelf stock. The non-procutable tubes were categorized by projected stock out date. Stock out forecast categories of 3 years, 3-5 years, 5-10 years and more than 10 years were selected. A summary of the resultant migration of categories is shown in Figure 2.

### Application Survey

One of the first actions was to request end item application data for the "non-procutable" tubes. After some initial confusion due to imprecise terminology, the survey was undertaken. The results, were inconclusive. One Military Department furnished some data promptly and was months late



| CATEGORY   | PROJECTED<br>STOCK OUT DATE | NUMBER OF ITEMS |              |              |               |               |
|------------|-----------------------------|-----------------|--------------|--------------|---------------|---------------|
|            |                             | 11 SEPT 1973    | 5 SEPT 1974  | 10 DEC 1974  | 21 MARCH 1975 | 24 APRIL 1975 |
| I          | WITHIN 3 YEARS              | 31 <u>3/</u>    | 68 <u>1/</u> | 56 <u>2/</u> | 43 <u>6/</u>  | 48            |
| II         | WITHIN 3 TO 5 YEARS         | 12 <u>4/</u>    | 28           | 24           | 15            | 15            |
| III        | WITHIN 5 TO 10 YEARS        | 95 <u>5/</u>    | 55           | 59           | 55            | 62            |
| SUB TOTALS | (CATEGORIES I-III)          |                 | 151          | 139          |               | 125           |
| IV         | BEYOND 10 YEARS             |                 | 181          | 189          |               | 202           |
| TOTALS     | (CATEGORIES I-IV)           |                 | 332          | 328          |               | 327           |

NOTES:

- 1/ NO ASSETS FOR 17 ITEMS  
2/ NO ASSETS FOR 15 ITEMS  
3/ LESS THAN ONE YEAR STOCK  
4/ LESS THAN TWO YEAR STOCK  
5/ LESS THAN TEN YEAR STOCK  
6/ NO ASSETS FOR 10 ITEMS

FIGURE 2



generating the remainder. A second responded by referring to previous interrogations which had requested similar information for 83 tubes declared non-procurable previously. Some of these tubes also appeared on the 136 tube list. Matching the incomplete responses to previous correspondence resulted in an inordinate amount of time being spent compiling and evaluating the responses. The third department partially responded months late. The results were unexpected. Applications ranged from obsolescent test equipment to first line military weapons system hardware. There was no discernable pattern of use trend toward equipment obsolescence, or plan for orderly equipment replacement.

#### Demand Forecast Adjustment Factor

The group attempted to test the ability of the Military Department and civil agencies to provide data useful in developing demand adjustment factors. Two samples were distributed. The first consisted of a purged list of the original non-procurable tubes. The second consisted of a list of tubes selected as being likely to become the next "non-procurable" tubes because they (a) were manufactured by only one remaining manufacturer, (b) and were of limited demand and (c) were in a minimal asset position.

The form used to conduct this survey is shown in Figure 3. Figure 4 is an excerpt from the instructions that were mailed with the survey form.

Although there was some information furnished for individual end item applications, the overall response was disappointing. A summary of the information was developed and a display constructed. This display is included as Appendix 5.

# VACUUM TUBE INQUIRY

| FSN                     | U/1 | U/C  | SV | CURRENT MONTH |       | CURRENT QUARTER |       | QTR. 1 PREV. |       |
|-------------------------|-----|------|----|---------------|-------|-----------------|-------|--------------|-------|
|                         |     |      |    | QTY           | FREQ. | QTY             | FREQ. | QTY          | FREQ. |
| 5960-060-6562<br>(5844) | EA  | 1.50 | AF | 5             | 2     | 4               | 2     | 130          | 18    |

## TURN AROUND DATA:

- A. PHASE OUT CALENDAR YEAR OF LAST EQUIPMENT REQUIRING TUBE
- B. CURRENT ANNUAL DEMAND \_\_\_\_\_
- C. CURRENT ON-HAND ASSETS \_\_\_\_\_
- D. PROJECTED ANNUAL DEMAND THROUGH PHASE OUT CALENDAR YEAR (REQUIRE NUMBER OF ENTRIES FROM

## PRESENT TIME THROUGH PHASE OUT YEAR)

|              |   |   |       |   |    |       |
|--------------|---|---|-------|---|----|-------|
| CURRENT YEAR | + | 1 | _____ | + | 6  | _____ |
|              | + | 2 | _____ | + | 7  | _____ |
|              | + | 3 | _____ | + | 8  | _____ |
|              | + | 4 | _____ | + | 9  | _____ |
|              | + | 5 | _____ | + | 10 | _____ |

USAF PREVIOUSLY COULD NOT VALIDATE A REQUIREMENT

FIGURE 3

## VACUUM TUBE INQUIRY

### Transmittal Letter Instructions Included:

"FOR THOSE TUBES WITH MULTIPLE APPLICATIONS, PLEASE PROVIDE FOR EACH FEDERAL STOCK NUMBER, A PROJECTED TOTAL DEMAND FOR EACH YEAR THROUGH THE EXIT YEAR OF THE LAST SURVIVING EQUIPMENT."

FIGURE 4

### Manufacturing Source Survey

Concurrently with the activity and surveys within government, the group sponsored a survey to update manufacturing source information for receiving tubes. This survey was conducted by the DESC procurement directorate. All known domestic tube manufacturers were asked to indicate which of the tubes in a list of 1640 tubes they could currently manufacturer. As shown in Figure 5, 241 of 941 receiving tubes are reported as having no current manufacturing source. However, not all 241 tubes will be in a buy position in the foreseeable future.

### MANUFACTURING SOURCE SURVEY

#### NUMBER OF TUBES WITH:

|                                  |     |
|----------------------------------|-----|
| <u>TWO OR MORE</u> MANUFACTURERS | 327 |
| <u>ONE</u> MANUFACTURER          | 373 |
| <u>NO</u> MANUFACTURING SOURCE   | 241 |
| TOTAL                            | 941 |

FIGURE 5



#### Group by Manufacturing Characteristics

An engineering study was undertaken to attempt to match groups of tubes with specific tube manufacturing facilities. This information would be of use in considering government owned or subsidized receiving tube manufacturing facilities.

The dominant piece of equipment is the Sealex machine. This machine accepts a raw bulb and interior tube assembly and automatically evacuates and seals the electron tube. Each bulb diameter requires a different size Sealex machine. All of the other fabrication and assembly operations are conducted on small free standing special purpose machines or bench type such as foot operated kick presses. With a Sealex machine installed, a manufacturer could generally fabricate or purchase all needed components for the tube and design and fabricate the necessary test equipment. Although ready availability of all needed parts and materials can no longer be assumed, nevertheless, the Sealex machine continues to be the determining element. Consequently a facility could be operated which would have the capability of making all of the tubes which could be accommodated in a Sealex machine and for which parts, the machinery, and materials necessary to fabricate them are still available.

This study indicated that receiving tubes generally fall into seven glass bulb categories, another for metal and ninth for all miscellaneous tubes, Figure 6. (A listing of the tubes in each group is available. It is too voluminous to be included in this report.) This study was intended to determine the technical feasibility of the concept, not the economic viability. The latter has not yet been addressed in specific terms. In conjunction with the overall manufacturing grouping survey, the Naval Ammunition Depot (NAD) Crane, Indiana, was asked to report on its ability to produce limited quantities



# MANUFACTURING CHARACTERISTICS GROUPS

| BULB TYPE |                 | NO. OF RECEIVING TUBES |
|-----------|-----------------|------------------------|
| I.        | T-3             | 112                    |
| II.       | ACORN           | 8                      |
| III.      | T-5 1/2         | 149                    |
| IV.       | 1-9             | 239                    |
| V.        | LARGE "T" BULBS | 112                    |
| VI.       | ST BULBS        | 88                     |
| VII.      | METAL           | 67                     |
| VIII.     | SPECIAL         | 16                     |
| IX.       | T-6 1/2         | 205                    |
|           |                 | 996                    |

FIGURE 6

of receiving tubes. The NAD Crane does have a capability and mission to rebuild high value electron tubes. It does not have the capability to economically produce in volume quantity, relatively inexpensive receiving tubes. No economic justification has yet been developed to demonstrate that a government receiving tube manufacturing facility at the NAD Crane would be more cost effective than subsidizing existing contractor owned and operated facilities. A government tube plant would also raise the question of assuring life, quality and performance characteristics equal to that already demonstrated by existing tube manufacturers.

## FINDINGS

1. The DVTSG has found that the allegations setting forth the situation in government and industry were substantially true.

### Within Government:

Receiving tubes are not automatically identifiable in FSC 5960.

No central file of application data exists for each DESC managed NSN.

Reutilization philosophy is unresponsive to receiving tube needs.

There are no formal procedures for advance alert of all echelons for requisitioning DoD Components.

Credibility was lacking.

Parochial Interests often resulted in reluctant cooperation.

### Industry:

Prices are escalating as economies of scale are lost.

Parts availability problems are increasing.

Production base is declining rapidly as operations are being consolidated or plants shut down.

Corporate plans are not being released.

2. No single technical solution exists for ameliorating the effect of lack of production sources for receiving tubes. Each generic solution has one or more major obstacles which is not likely to be overcome in all instances. Eight generalized solutions and their drawbacks are shown in Figure 7. For each National Stock Number, the most economical action will depend on factors such as demand, end article application(s) and density, remaining operating life expectancy, non-recurring (start up) costs, etc.

3. No governing procedure exists for gathering the data required to determine the appropriate action(s) to undertake when the last manufacturing

POSSIBLE LONG RANGE "SOLUTIONS"

| "ANSWER"              | DRAWBACK(S)  |
|-----------------------|--|
| SUBSTITUTION          | ONE IS NOT ALWAYS AVAILABLE  |
| PLUG IN SEMICONDUCTOR | HASTEN DEMISE OF REMAINING TUBE MANUFACTURERS; LOW VOLUME ITEMS NOT OF INTEREST TO SEMICONDUCTOR MANUFACTURERS |
| SUBSIDY               | NO BASIS OR AUTHORITY  |
| APPORTION MARKET      | ANTI-TRUST   |
| LAST BUY              | NOT ALWAYS OFFERED, QUANTITIES NEEDED UNCERTAIN, MOBILIZATION IMPACT   |
| REPLACE EQUIPMENT     | HIGH COST; NO SYSTEM TO ESTABLISH PRIORITIES COMPLICATED BY MULTIPLE APPLICATIONS                              |
| SECONDARY SOURCES     | UNCERTAIN QUALITY AND AVAILABILITY   |
| GOVERNMENT FACILITY   | NO POLICY; COMPONENT NOT ALWAYS AVAILABLE; HIGH COST; SKILLS LACKING;  |

FIGURE 7



source for needed receiving tubes has ended, or is about to end, production. There is no policy instrument, guidance or joint agreement as to the individual and collective responsibilities of affected agencies. Existing directives, regulations and instructions do not comprehensively address this problem. Some procedures, such as reutilization visibility thresholds, acceptance criteria for excess stock, and economic order quantity calculation requirements hinder, rather than help, affirmative action.

4. There is no management requirement for determining the remaining inventory life of the end article applications for most receiving tubes. In those cases where a format exists, many entries for end article life forecasts are inaccurate or are coded "indefinite." This provides no basis upon which to estimate remaining total life cycle quantities of needed tubes.

5. Current practices do not permit timely determination of end article application and the forecasted remaining life of equipment furnished in accordance with international security agreements. No central data bank exists nor is there any procedure for summarizing the total end article equipment density or quantity, condition, or forecasted remaining life. Responsibility for various facets of this support are scattered and timely responses to requests for materiel management information are not furnished.

6. Development of a central file to contain end item application data for all consumable items is not feasible at this time. Time and budget constraints limit this activity to selected consumable items only. It is possible to use current Military Standard Requisitioning and Issuing Procedures (MILSTRIP) to begin to build a data file of selected items at the DESC. This procedure is shown in the Diagram in Figure 8. Later, implementation of the Defense Integrated Data System (DIDS) will create a file space for 55,000 selected consumable items with integrated management at the Defense Logistics Services Center which could replace the DESC file.



PROPOSED INTERIM DATA BANK BUILDING PROCEDURE

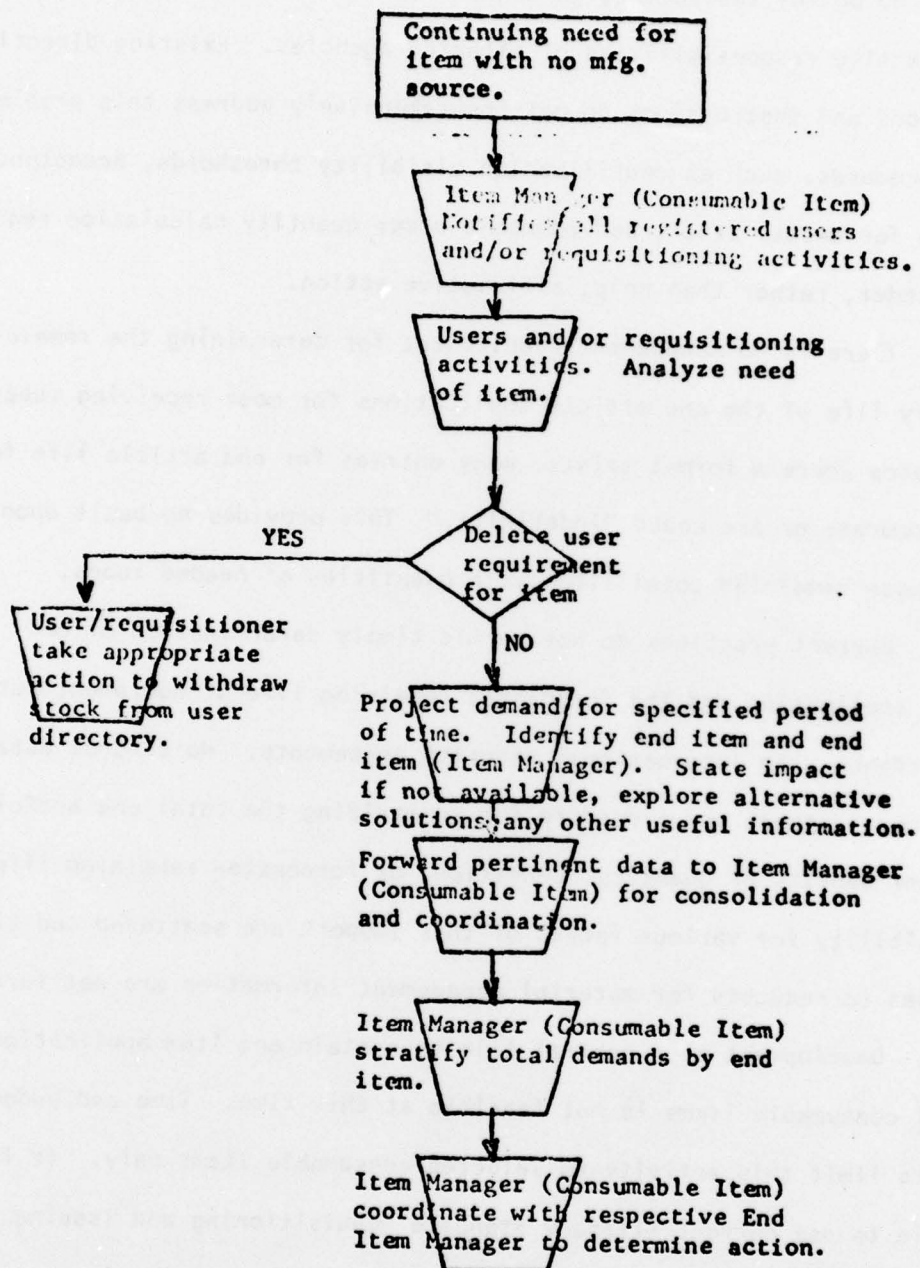


FIGURE 8

## Recommendations

The following recommendations are divided into short term (completed within a year) and long term actions. Immediate direction and guidance are necessary to promptly begin to intensify efforts to ameliorate the impact of diminishing production sources for receiving tubes on the existing inventory of tube powered electronic equipment. A long range continuing program to improve and automate activities implemented in the short term should then be undertaken.

### A. Short Term

1. Issue a DoD Directive specifying the responsibilities of the integrated manager and the requisitioning commands. The direction should contain guidance as to the specific actions and procedures the DSA and Military Departments should institute to implement the intent of the directive.

2. The Military Departments and the DSA should issue a joint implementing document specifying the responsibilities that each is to assume in order to solve any lack of manufacturing source problem for a consumable item. It may be possible to modify DSA Regulation 3200.1, Engineering Support for Items Supplied by Defense Supply Agency and General Services Administration. The new document should specify operating procedures for assuring timely liaison and coordination in the context of existing materiel management procedures.

3. Temporarily utilize "demilitarization" precious metal recovery program or other procedures to code selected National Stock Numbers to preclude disposal action until the integrated consumable item manager has been given the opportunity to claim excess for stock. An existing code could be redefined to include disposal procedures for items which must be recouped. This procedure could be an interim plan until a separate code

symbol is instituted to describe NSN's of nominal original value which may not be disposed of without the expressed approval of the integrated item manager because they are no longer obtainable at a reasonable cost.

4. A steering group should be convened to continue actions necessary to include in forthcoming automated materiel management procedures improved practices for dealing with situation of no manufacturing source for consumable items. Among the tasks this group would address are those longer range recommendations which follow.

B. Long Term

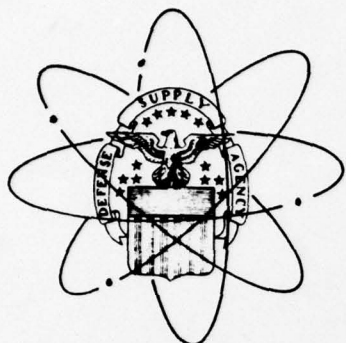
1. Consistent with product shelf life, develop and institute formal procedures for including "last buy" funds in "wholesale" stock fund budget process. This would permit a timely response to last buy opportunities now lost due to current lengthy budget planning procedures. Develop budgetary procedures to allow a subsidy for existing contractor owned facilities or develop guidelines for possible creation of a government owned production facility. (The latter action should be undertaken only after all other possible solutions have been exhausted.)

2. Create an end item application file for selected National Stock Numbers (NSN). Develop procedures for maintaining current information in this file and for purging from it those NSN's which are no longer of interest. Include in this file, a forecast by year of future density or quantity of each end article or latest date by which end article will be phased out of inventory. Develop associated procedures for the Engineering Support Activity to provide initial data and confirm or update at least annually. Develop priorities, if necessary, to determine either which equipment will receive remaining stocks of consumable items, or which end article equipments should be funded for replacement, or both.



3. Integrate improved procedures for dealing with problems of no manufacturing source into current and planned automated materiel management process. This entails all aspects of: (1) identifying problem consumable items; (2) notifying affected agencies; (3) developing and transmitting needed information; (4) assessing financial implications, schedule requirements, utility, and effect on military capability of alternative actions; (5) implementing the appropriate decision; and (6) notifying all affected of the action taken.





# DESC CUSTOMER INFORMATION BULLETIN

Vol. VIII, No. 3

Defense Electronics Supply Center, Dayton, Ohio

January, 1977

## DESC May Have To Ship Commercial Tubes Instead of MILSPEC Parts

The 1 August 1976 closure of the RCA production facility at Harrison, New Jersey eliminated, at least temporarily, DESC's source for production of several MILSPEC electron tubes. As an interim support measure, we procured a significant quantity of the commercial version of the affected tubes, and in most cases, currently have them on hand ready for issue. The Army, Navy and Air Force activities responsible for the applicable Military Specification have concurred in reversal of the standardization coding, i.e., with usage of commercial equivalents in lieu of items controlled by Military Specification.

In the future, as assets are depleted on the MILSPEC NSN, DESC will issue the commercial NSN/tube without contacting the requisitioning activity. In time we hope to develop a new source and acquire more MILSPEC tubes. The following cross-reference list of the tubes involved is provided for your information. Any questions/comments concerning this subject should be directed to DESC-STH, (AV) 850-5161.

| TUBE TYPE | 5960<br>MILSPEC NSN | 5960<br>COMMERCIAL NSN |
|-----------|---------------------|------------------------|
| 7586      | 00-060-6613         | 00-755-0184            |
| 1L4       | 00-100-5130         | SNTBA*                 |
| 6SQ7      | 00-100-5273         | 00-617-8611            |
| 6SH7      | 00-100-6041         | 00-617-3642            |
| 12SQ7     | 00-100-7084         | 00-617-9087            |
| 12SY7     | 00-100-7087         | 01-019-6703            |
| 26A7GT    | 00-100-7111         | 01-019-6704            |
| 83        | 00-100-7323         | 00-615-5603            |
| 884       | 00-108-0257         | 00-615-5649            |
| 6V6       | 00-114-3809         | 00-100-5893            |
| 12SA7     | 00-116-9938         | 00-114-3816            |
| 12SG7     | 00-116-9948         | 00-100-6040            |
| 12SK7     | 00-116-9949         | 00-617-9138            |
| 6BA7      | 00-188-0806         | 00-615-4744            |
| 12A6      | 00-188-0930         | 00-617-8950            |
| 1A3       | 00-188-3527         | SNTBA*                 |
| 3Q4       | 00-188-3540         | SNTBA*                 |
| 0A3       | 00-188-3565         | 00-557-6929            |
| 6SG7      | 00-188-3572         | 00-617-3628            |
| 1S5       | 00-188-3952         | 00-556-1243            |
| 5691      | 00-188-6605         | 00-615-5601            |
| 6C5       | 00-188-8500         | 00-617-3635            |
| 6F6       | 00-188-8504         | 00-617-9113            |
| 6L7       | 00-188-8527         | 00-617-3632            |
| 6K7       | 00-188-8535         | 00-617-8929            |
| 6J7       | 00-188-8538         | 00-617-3633            |
| 6AF6G     | 00-188-8564         | 00-617-8946            |
| OD3       | 00-188-8573         | 00-615-4732            |
| 5Z4       | 00-188-8600         | 00-617-3629            |
| 3A4       | 00-188-8617         | 00-556-1807            |
| 3A5       | 00-188-8627         | 00-581-8458            |
| 6F5       | 00-228-0018         | 00-615-5685            |
| 6012      | 00-296-3369         | 00-296-2464            |
| 8058      | 00-924-6987         | 00-710-2769            |
| 7895      | 00-958-0073         | 00-074-8968            |
| 7587      | 00-958-0080         | 00-892-0928            |
| 8056      | 00-985-9146         | 00-050-4588            |
| 12SH7     | 00-989-1251         | 00-617-3627            |

\*Stock number to be assigned.