Federal Wage System Job Grading Standard for the Introduction to the Electronic Equipment Installation and Maintenance Family, 2600

Table of Contents

RATIONALE FOR SERIES COVERAGE

The Electronic Equipment Installation and Maintenance Family covers all occupations and jobs the duties of which are to supervise and/or perform work involved in installing, repairing, overhauling, fabricating, tuning, aligning, modifying, testing, calibrating, and inspecting electronic equipment and related devices. This equipment includes AM/FM radio broadcast receivers, high fidelity record players and tape recorders, and TV receivers; public address systems; radio communications receivers and transmitters; radar, loran, and sonar; radio teletype units; low frequency, broadband, and multichannel broadband carrier systems; mobile and fixed television systems and equipment; computers; air traffic control equipment and systems; electronic industrial controls; electronic measurement equipment; cryptographic coding and decoding devices; digital telephone switching centers; and other similar systems and equipment.

The family is made up of five specific series, for which standards have been or will be written, and one general catch-all series.

The broadest coverage is found in the Electronics Mechanic, 2604 series. This covers work on diverse electronic equipment and systems, radio, radar, public address, security, etc. The other four series have more specific criteria. If a job does not match the specific criteria of one of these four series, it should probably be placed in the Electronics Mechanic Series, 2604. Only in highly unusual circumstances when it is clear that the criteria of none of the five series apply to the job should the job be placed in the "catch-all" 2601 series. (For further discussion of "01" series, see the Introduction to the Job Grading System for the Federal Wage System.)

The three most specialized series, Electronic Measurement Equipment Mechanic, 2602, Electronic Industrial Controls Mechanic, 2606 and Electronic Digital Computer Mechanic, 2608, are established on one or more of the following bases:

- A sizeable population performing duties generally recognized as an occupation.

- Working on specific types of equipment which require different specialized applications of general trade principles or skills for understanding of circuitry or precision of adjustment.

- A critical occupation for which agencies need grade level guidance, irrespective of size.

The fifth occupation, Electronic Integrated Systems Mechanic, 2610, covers work which requires extensive knowledge of a number of electronics applications such as development and propagation of signals, measurement of forces, computation of data, and control systems, as well as mechanical and hydraulic knowledge. What sets this occupation apart from the other electronics occupations is the fact that it encompasses all these areas in an integrated complex, i.e., the various portions of the system are connected in an information loop so that information detected triggers an action by another portion of the system which then feeds back and updates the initial information. The key factor for this occupation is the need for the employee to draw *simultaneously* on the complete range of electronic, mathematical, and mechanical knowledges comprising the system in order to understand and repair the equipment.

DETERMINING WHETHER WORK IS WAGE GRADEOR GENERAL SCHEDULE

General criteria for determining whether a job is a General Schedule or a Trades and Labor job are contained in the Guidelines for the Determination of Trades, Crafts, or Manual Labor Positions, Section IV of the Office of Personnel Management's Introduction to Position Classification Standards. Broadly, the determination should be based on the paramount requirements of the work in terms of the functions performed and the qualifications required. The following criteria have been developed in relation to these general criteria, and are to be used in conjunction with the general criteria to determine whether jobs in the electronics field are General Schedule or Trades and Labor electronics jobs.

In most occupations, the skill, knowledge, and abilities which employees bring to the job are significantly different from those required for other occupations. Unfortunately, this is not a reliable measure of the difference between electronics mechanics and electronics technicians. To illustrate, the following list of KSA's are required to some degree in most technician and mechanic positions:

- theoretical knowledge about the fields of electricity, electronics, and physics;

- knowledge of the capabilities, limitations, operations, design characteristics, and functional use of a variety of types and models of electronic equipment and systems;

- ability to understand how and why a specific device or system embodying electronic principles operates;

- understanding of electronic circuitry and associated wave forms;

- knowledge and understanding of the kinds of circuits to be used to produce specific results;

- ability to apply general knowledge of electronics and to transfer experience and knowledge from one kind of equipment to another;

- knowledge and understanding of how external forces such as geographical and climatic conditions and other electronic or physical devices affect the functioning of electronic devices, and what methods may be used to counteract such forces; and

- knowledge and understanding of concepts, principles, techniques, criteria, data, and practices relating to matters such as the following:

    - fidelity of transmission of wave forms
    - elimination of interference and distortion
    - modulation and demodulation of wave forms
    - pulse techniques
    - precise timing, synchronization, switching, control, and trigger circuits
    - radiation and propagation of electromagnetic waves

- conversion of electrical, magnetic, mechanical, optical, and other stimuli into forms suitable for measurement or process controlled;
- skill in the use of hand and power tools and in wiring, construction, and assembly of components.

The differences between the electronics mechanics and technicians are not so much in the types of skills, knowledges, and abilities possessed but in the degree to which they are possessed and the manner in which they are used. Trying to determine and explain the degrees of skill and knowledge needed to perform wage grade and general schedule work at various grade levels would lead to even greater confusion. As a result, the discussions following focus primarily on the observable differences in the functions performed.

Based on the clear-cut nature of the duties and responsibilities assigned many jobs in the electronics field are easily identified as being either electronics mechanic or electronics technician jobs. Many additional jobs are easily differentiated even when some similar duties are performed. Examples of such work situations are:

Repair: Repair of electronic systems and equipment of the type generally performed in overhaul shops is characteristically a trade function. Such work includes detecting and diagnosing malfunctions, tearing down equipment, repairing or replacing parts or components, and aligning and calibrating and testing the modified or repaired equipment. positions in which the performance of such repair function is the *paramount* requirement are trades positions.

By contrast, General Schedule technicians perform similar work in connection with the *paramount* requirement for performance of engineering functions such as developing and designing test and repair equipment, analyzing present repair practices and developing procedural instructions for use by others on methods and steps of equipment repair, or conducting engineering evaluations of the adequacy of such things as the test and calibration equipment used in making repairs.

Maintenance: Performance of preventive and corrective maintenance to keep electronic equipment and systems in reliable operation is characteristically a trade function. Such work includes periodic servicing to assure reliable operating condition and to extend service life, inspecting and testing equipment for compliance with specified standards of performance, calibrating and aligning the system, diagnosing and correcting malfunctions, removing malfunctioning systems from service, and doing bench repairs necessary to restore the equipment to the prescribed operation standards and tolerances, and, sometimes, certifying the equipment is operating properly. Positions in which the performance of such preventive and corrective maintenance is the *paramount* requirement are trades positions.

By contrast, technicians in General Schedule positions perform similar maintenance work in connection with the paramount requirement for performance of engineering functions such as the development of maintenance standards and procedures for use by others, the engineering test and evaluation of new or modified electronic systems, or analyzing the compatibility of interlocking components, systems, and equipment for the purpose of redesign of the equipment to increase compatibility.

Installation: Installation of electronic equipment in accordance with plans, specifications, and detailed instructions, or reinstallation of a repaired or modified system, is characteristically a trade function. Such work includes arranging and interconnecting equipment, testing installation for compliance with standards and tolerances, and calibrating and tuning systems. Positions in which the performance of such installation work is the *paramount* requirement are trades positions.

However, responsibility for planning and directing the installation of complex electronic systems and associated facilities, particularly where there are problems of site selection and construction, dealing with contractors and public utilities, and modification of the equipment to adapt to novel site characteristics, frequently requires engineering competence. In such cases, the nonprofessional employees who perform this coordinative and technical installation work, with or in lieu of an engineer, are in General Schedule positions.

Fabrication: Fabrication of electronic equipment in accordance with plans, specifications, and instructions is characteristically a trades function. Such work includes constructing, assembling, arranging, mounting, and wiring electronic parts and components to produce breadboard, laboratory, or operational models. Positions in which the performance of such fabrication work is the *paramount* requirement are trades positions.

By contrast, electronic technicians perform similar fabrication work in connection with broader responsibilities for development or evaluation of electronic equipment. The technician is typically and primarily concerned with the design and analysis of circuits, determining feasibility of the designs, evaluating equipment performance under varying environmental conditions, collecting data, or designing or modifying designs to achieve objectives of performance and cost. Also, electronics technicians in development organizations may perform fabrication duties which are wholly identical to those of the electronic mechanic where the technician position is identified as being in a training or career development program leading to development technician positions.

Testing: The performance of testing which is an inherent part of a trades function such as repair, maintenance, installation, and fabrication is characteristically a trades function. Such work includes making measurements to diagnose malfunctions, to align and calibrate equipment, and to assure that equipment operates within prescribed standards and tolerances. Also wage grade, is testing to provide data by which others can evaluate R&D progress or adherence to regulatory requirements. Positions in which the performance of such testing work is the *paramount* requirement are trades positions.

> By contrast, electronics technicians perform similar testing work which is an inherent part of engineering functions assigned to them concerning projects such as the development or evaluation of new or modified electronic systems or monitoring of frequency emissions by licensed stations. In these cases, they not only do the testing but evaluate the data and form engineering conclusions as to acceptability of equipment modifications, validity of test procedures and data, or legality of operation.

The examples discussed above cover the large majority of nonprofessional jobs in the electronics field. They present no particular problems in determining the appropriate pay system. There remain some jobs which are assigned duties and responsibilities in such a way that it becomes very difficult to distinguish the mechanic from the technician. Close scrutiny of the work is required.

A basic difference between the technician and the mechanic is in the mental approach to the problems faced. The technician uses electronic theory, mathematical knowledge, etc., as the basis for "new thought" to solve practical engineering problems in conventional areas of endeavor, e.g., design and construction of amplifier circuits, pulse forming networks, etc., at conventional frequency and power levels, where almost all the detailed engineering work performed requires only limited reference to basic scientific considerations. Most of the engineering problems have been repeatedly encountered by engineers. The methods of attack on the best solution have been established and formulae, guides, and typical circuitry have been developed and published in numerous textbooks and handbooks. The selection and application of the information to the practical problems encountered is typical of technician positions.

The mechanic, on the other hand, uses a similar background of electronic theory, mathematics, and experience as the basis for "second thought", i.e., to follow and understand the design concepts of others, to understand the purpose and operation of parts and circuits, to follow signal flow through assemblies and components and recognize proper wave forms and signal values in order to tune equipment for optimum performance and to locate and correct malfunctions.

In practice, this distinction is blurred somewhat by the innovative ability of many experienced electronics mechanics. This ability is exhibited in the development of shortcut procedures, test jigs and fixtures of various kinds to make their work faster, easier and/or more reliable; the recognition and recommendation of correction of errors in documentation or procedure; or recommendations of methods, design changes, etc., to remedy the deficiency.

In these cases, it is significant to note that while the mechanic's performance tends toward that of a technician, it is in response to a random condition or need. It is often valuable to and recognized by the activity but it is not an ongoing need of the activity, i.e., is not required by management, and its absence is not cause for negative action by the supervisor against the employee. It is a requirement, however, that the electronics mechanic exercise journeyman level competence in testing, repair, or other assigned work.

Operating functions may bear on the determination of general schedule or wage grade status. There are some cases in which the equipment being maintained is in a system where public safety depends on the continuous or substantially continuous operation of the equipment at tolerances which are very close to optimum equipment performance. In these cases the paramount requirement of the position may be unreviewed evaluation of factors such as equipment operating trends in order to identify approaching maintenance requirements and to consider predicted traffic loads on the system, capability and availability of alternate routing and transient factors influencing increased demand to determine periods of minimum interference with system operation, in order to decide whether or when to schedule maintenance early, keep equipment operating at marginally acceptable accuracy or immediately shutdown the system. Such knowledge, and direct responsibility for public safety, is not characteristic of wage grade positions. Where it can be documented that employees have the authority to shutdown critical portions of such a system upon their determination that the shutdown will have minimum adverse impact on operations, the position is properly classified as an Electronics Technician even though the maintenance and repair work performed would be wage grade.

Some electronics jobs may on occasion fail to show the paramount purpose even after the closest scrutiny. In such cases, it may be necessary to consider other factors as a help in making the distinction. For example, the nature of the organization (R&D, maintenance depot, etc.) may give some indication of the predominant character of the work that is most likely to be assigned to the electronic jobs in that organization.

The relative level and time spent on Trades and Labor functions and General Schedule type work may furnish some help. In this instance, it would be necessary to look at such things as functions (Trades and Labor or General Schedule) on which the preponderance of time is spent and, determine what the grade level worth would be for the Trades and Labor functions as opposed to that of the General Schedule work performed. (This may give some *indication* of the basic purpose and primary qualifications requirement of the work. Percentage of time is not a determinant in pay category issues.)

Lastly, management's intent in creating the job may be looked at. In this instance, it would be necessary to identify the purpose (in terms of *primary* functions) for which the job was intended, the relationship of the job to others in the organization and the line of future promotion for employees in the job.

COMPLEXITY OF EQUIPMENT vs. COMPLEXITY OF WORK

Classifiers and other users of these standards must avoid the simplistic approach of determining grade level solely by comparison of the complexity of the equipment worked on to the complexity of equipment given as examples in the standard. They must evaluate the work actually being performed. For example, as a result of technological innovations such as standardized microcircuitry and quick change circuit boards, many repairs can be made by plugging in known good boards or components in accordance with explicit instructions which are keyed to easily observable symptoms. In such cases, the total complexity of the unit under repair may be very great, for example, a high powered radar set or a large computer. However, the complexity of the assignment is not proportional to the equipment complexity nor is it required that a great degree of electronics skill and knowledge be possessed by the employee.

The job must be carefully studied to determine and evaluate the skill and knowledge actually needed by the employee to perform the work.

IMPACT OF TECHNOLOGICAL DEVELOPMENT

Questions are raised about the impact of technological change on the electronics occupations. One aspect of technology is the development of integrated circuit chips, of large scale integrated circuit chips with tens of thousands of transistors on a chip less than a postage stamp in size, and of multichip hybrid packages. Another aspect is the development of programmable digital electronics circuits in which modular elements can be used in more than one system. A third is development of automated testing equipment and circuit board diagnostic equipment. There are many more developments on the drawing boards and the test benches.

The introduction of transistors and printed circuit boards in the 1950's at first had relatively little impact on installation, maintenance, and repair functions. Equipment got smaller, lighter, and little more reliable but repairs still involved locating and replacing individual parts in individual circuits which were individually designed for the particular purpose and piece of equipment and were hand assembled.

The various levels of integrated circuits (IC's) developed in the 1960's and still continuing, have allowed the introduction of new concepts of circuit design. In the past, engineers designed circuits around existing, standardized electron tubes and transistors. Now it is possible to design items of equipment around existing, standardized integrated circuits. The variety of types and the low cost of such circuits have led to many new applications which involve digital computers, digital signal processors, microprocessors, multiplex systems, displays, control panels, interface units, and programmable modular units. The systems which use these elements are characterized by smaller size and greater functional complexity and accuracy than the earlier, discrete component tube and transistor circuits. To counterbalance the increased difficulty of understanding the more complex equipment, the difficulty of troubleshooting and repair often has been decreased because the equipment has been built in modular form and, often, with fault isolation test capability which speeds the troubleshooting. In addition, it is often necessary only to isolate a group of circuits, instead of an individual resistor or capacitor in an individual circuit since whole integrated circuit chips or multichip packages are replaced. These two factors frequently offset each other so that there is no grade level impact. When evaluating complexity of work performed, the classifier must consider the type of circuitry used in the equipment and the difficulty in working with it as well as the functional complexity of the equipment.

Another technological development is beginning to be used. This is the growth of computer controlled automatic test equipment (ATE) complexes. The development of ATE's coincides with the development of integrated circuits and digital electronics. IC's and digital electronics make possible the complexity of the ATE and, at the same time, allow standardized, software controlled subunits for which it is practical to design test jigs and programs.

The ATE is composed of a control computer, switching devices, and various signal generators, power supplies, analyzers, oscilloscopes, and other test equipment which are set by the computer to provide the proper stimulation and take the readings needed to test the specific unit under test. The results are then compared with the design standard in the computer memory. If the result is within specification, the ATE performs the next programmed test. If not, the operator is notified of the location of the malfunction. The stated purposes of the ATEs are to provide high reliability maintenance capability, at low unit cost, with less skilled operators. When properly designed, installed, and programmed for the unit under test, the purposes are achieved. Relatively low skilled operators are able to "follow-the-book" to test and repair complex units. This is another example of the caveat given above. The complexity of the operator's work can not be measured solely by the complexity of the units under test or of the test equipment.

On the other hand, new or modified units under test require new software, new interconnecting units and, sometimes, additional test equipment. Experience has shown that these changeovers are not smooth. The newly introduced software especially, introduces problems which are beyond the capability of the usual operator to solve. It is likely that one or more employees at an ATE installation will need full knowledge of the total ATE, the unit under test, and computer programs in order to recognize deficiencies in the test equipment, programming, or unit under test and to work with engineering personnel to correct them. In these cases, the total complexity of the assignment and the skill and knowledge required of the incumbent will be greater than that required for traditional bench test and repair of the units under test.

In summary, the recent technological changes have had little impact on typical grade levels of the electronics occupations. Employees working with the new technology will find it necessary to update their knowledge but, for most employees, the new knowledge is different from but not greater than the level of skill and knowledge of the older technology.

AGE OF EQUIPMENT

Work on so-called state-of-the-art equipment is often cited to support a higher grade. The rationale for this is the need to exercise greater than usual skill, knowledge, and responsibility in order to cope with obscure malfunctions caused by lack of design, construction, maintenance and operation expertise with the new concepts. Some electronics standards include this situation.

There are pitfalls which must be considered before a job is graded on the basis of state-of-the-art knowledge and responsibility. In the first place, most new equipment is not truly state-of-the-art. Rather, it is an evolution of design concepts previously used and proved. The technical experts should be able to provide justification to claims that an equipment or system represents application of a technological breakthrough. A second pitfall is the claim that employees need greater skill and knowledge to suggest modifications to equipment design and maintenance because of state-of the-art created deficiencies. If this is a very strong element in the job, the classifier must consider whether the work is not more properly placed in a General Schedule occupation. Further, evidence of continuing input is important. Occasional suggestions, which are rewarded by beneficial suggestion awards, should not be used to support the assignment of a higher grade on this basis. The third pitfall is the rapid evolution of the electronics state-of-the-art. As experience is gained with new and untried systems, they cease to be state-of-the-art. A body of knowledge grows up. Needed modifications are made. The equipment remains but the concepts have evolved into well understood standard technology. Except at a few R&D activities which have frequently changing assignments, there is no further justification for advanced grades and painful cutbacks must follow. A full position management review of state-of-the-art positions should be made before the jobs are graded to be sure there is not a better long-term organization of work.

The opposite claim is for extra skill, knowledge, and responsibility requirements in positions which work with very old, outmoded equipment. The rationale for this is the extra skill, knowledge, and initiative needed to overcome problems of lack of parts, missing or inaccurate documentation, and instability of circuitry due to component aging. Here too, cases which could actually support such a finding are scarce. The situation usually has compensating factors. For instance, most equipment which has been in use for a long period has been kept in service because it is reliable. The technology is relatively simple to understand and the components were designed with fairly broad tolerances so the affects of aging are not as pronounced as with highly stressed modern equipment. Furthermore, in the years of service, unsatisfactory circuits have often been reengineered and updated to improve problem areas.

With both "state-of-the-art" and antiquated equipment, careful analysis is necessary to determine whether there is sufficient increase in the level of skill, knowledge, and responsibility required to justify an additional grade.

RELATIONSHIP WITH ELECTRONIC INTEGRATED SYSTEMS MECHANIC

The 2604, Electronics Mechanic Series covers work on one or a number of types of electronic devices and systems such as Hi Fi components, commercial TV receivers, TV central antenna systems, public address systems, radio transmitters and receivers, radar sets, sonar, loran, aeronautical navigation aids such as Tacan and VOR, industrial X-ray, and cryptographic equipment.

This equipment varies greatly in purpose and complexity. A common factor among these systems and equipment is what we have chosen to call linear signal flow. (This is not to be confused with the engineering meaning of linear circuit which is that the output is directly proportional to the input.) Linear signal flow is the situation in which the signal moves from the input to the output of the equipment without significant deviation or feedback looping. An example of this is a radio transmitter. The signal starts from two sources, an oscillator and a microphone. The carrier frequency signal from the oscillator progresses sequentially (linearly) through one or more frequency multipliers and amplifiers until it is powerful enough to be transmitted. The voice signal passes through several amplifier circuits, unchanged except in strength until it is powerful enough to modulate the radio frequency signal from the oscillator. The modified signal is then transmitted. Both portions of the signal pass directly (linearly) from the point of origin to the antenna. Feedback is used in such circuits to control frequency shifting or prevent amplifiers from becoming unstable but it does not cause a significant modification to the basic signal.

Another example of linear signal flow is a radar set. A timer supplies synchronizing signals to a transmitter, indicator, and associated equipment such as target identification equipment (IFF). The timing signal travels linearly through a number of circuits such as limiters, amplifiers, and peaking circuits to an output as a synchronizing pulse. The synchronizing pulse to the transmitter travels linearly through amplifier circuits to the radio frequency (RF) generator, a special tube called a magnetron or a klystron. The signal from the RF generator, which is now in the form of a pulse of radio frequency energy, travels to the antenna and is radiated. The return signal from a target, a weak radio frequency pulse, travels from the antenna to the receiver. Here, step-by-step, one circuit after another the signal is reduced in frequency, amplified in strength and sent to the indicator. In the indicator, the timing pulse is used to start a sweep on the cathode ray tube and the target signal places a pulse or target indication on the tube. In and between all of the units of the radar the signal travels in a direct line from origination in the timer to display on the indicator. Feedback is sometimes used in or between circuits to achieve stable operation but it has little effect on the form or information carried by the signal.

The 2610, Electronic Integrated Systems Mechanic Series, covers work on complex electronic systems where the output of a number of sensor subsystems is integrated in a logic subsystem and the resultant used to modify the operation of the total system. Some (not all) fire control, flight simulator, flight control, automatic test equipment, and navigation systems are of this complexity. A common factor among these systems and equipment is what we have chosen to call the electronic integrated system, in which several functions are combined and interact to serve a given purpose. Critical to the determination that a system is "integrated" are the type of subsystems and the signal paths by which they are interconnected. The electronic integrated system must have a number of sensing subsystems, one or more actuating subsystems, and a central data processing subsystem. The computer receives the output from the sensors, combines the information, and directs the operation of the actuators. The computer then receives feedback information, either directly or through the sensors, by which it monitors performance and modifies the operation of the actuator. In some instances, performance of sensors is modified as well.

The terminology of this explanation is confusing due, in part, to the many and varied meanings of the term system. In the minds of some users, the transmitter and receiver portions of a hand held citizens band radio comprise two complete systems. At the other extreme, the complete electronics installation on a major combat aircraft is regarded as a system. This diversity is so great and so well established that it is not practical to expect uniform usage of terms by subject matter experts nor even between different FWS standards, since they reflect the major usages of the occupation covered. The classifier must understand the meaning of the terms as used in the particular standard and determine the relationship to the terms and equipment associated with the job to be graded.

A widely known antiaircraft missile fire control "system" or complex provides examples of both a number of "linear" systems and an integrated system. The main units of the fire control complex are target acquisition radar, target tracking radar, missile tracking radar, computer, launcher and missile.

The target acquisition radar is a linear system. It is a long range search radar which presents a picture of the possible targets on a specialized cathode ray tube (PPI scope). The operator is able to select a single target from the number of targets displayed on the PPI and transfer the location data to another console where another operator manually synchronizes the target tracking radar with the displayed coordinates of the target. The operator then switches the target track radar to automatic tracking mode. The target tracking radar is another linear system. The data on target position are fed into the computer to be compared with the data from the missile tracking radar.

The missile tracking radar is a more complex linear system since it not only continually tracks the missile but associated circuitry communicates course corrections to the missile and receives status reports. All data are fed to the computer.

The electronic analog computer is the integrating force which converts these separate year systems into an integrated system. The acquisition radar, although part of the overall fire control system, is not part of the integrated system. The acquisition radar does not interface with the computer. Human operators observe the data, make the decisions as to primary target, and transfer target data into the target tracking radar.

The integrated system is comprised of the target tracking radar, the missile tracking radar, the computer, the launcher and the missile.

The computer receives information on the target position and, from the series of position inputs, predicts where the target will probably be a short time in the future. From the missile tracking radar the computer receives position, heading, attitude and speed information. The computer compares the positions of the target and missile, adds in the missile flight situation and determines the flight commands to send to the missile to direct it toward the target. The continuing flow of missile position and attitude data provides the feedback which the computer needs to send course corrections until the missile is guided to the target.

Why are not all fire control, flight control, etc., systems included in the 2610 occupation? Many require electromechanical skill and knowledge as the paramount requirement. Others, which are electronic, do not reach the level of complexity of the fairly simple integrated system described above. An example of this lesser complexity is an electronic autopilot which detects minute error signals from a stable platform and amplifies these to drive aileron or elevator servos in which the amount of displacement of the control surface is proportional to the amount of the error signal. This is a simple linear system. The addition of some control inputs to allow turns, climbs, etc., would not change the basic linear signal flow of an error sensing system. Such a system is covered by the Electronics Mechanic Series, 2604.

RELATIONSHIP WITH NONELECTRONICS OCCUPATIONS

A number of occupations which do not fall within the 2600 family do require some knowledge of electronics. This is an increasing phenomenon as the reliability and low cost of electronics based circuits are utilized in controls and equipment. In some jobs the impact has been so great that the predominant skill and knowledge has changed to electronics and the work is properly graded in the 2600 family. Examples of this are cryptographic equipment and digital switching centers. Historically, cryptographic equipment and telephone switching centers were of electromechanical design and work on these units came under the Wire Communications Equipment Installation and Maintenance Family, 2500. Work on the older equipment still in use remains in this family. The new generations of computer based digital equipment, however, require a depth of electronic knowledge which places the work in 2600.

More common are occupations where electro-mechanical controls have been superseded by solid state devices based on electronic technology. Examples of occupations where this has taken place are: Heating and Boiler Plant Equipment Mechanic, 5309; Bowling Equipment Repairing, 4819; Electrical Equipment Repairing, 2854; Electrician, 2805, Optical Instrument Repairing, 3306 ; and Office Appliance Repairing, 4806. The electronic based devices are commonly thought to increase the depth of complexity of skill and knowledge required by the employee. Usually this is not so. In most cases, the devices substitute simple and reliable electronic based equipment for intricate and unreliable mechanical or electro-mechanical devices. For the most part, the electronic based devices are so limited in scope of operation and complexity of design that adjustment and repair can be done in accordance with step-by-step instructions for which little or no electronics knowledge is required. There is no grade level impact whether the employee is working with such devices or with electromechanical or mechanical substitutes. The electronic based knowledge is different but less than the other knowledge and skill used and is not series controlling.

In other cases, work on electronic based devices is found at a higher level, such as Electrical Equipment Repairing, 2854; Medical Equipment Repairing, 4805, Elevator Mechanic, 5313 and Optical Instrument Repairing, 3306. The accuracy or other capability of the electronic based devices is used in applications that would not be practical otherwise. The overall complexity of the unit is increased and the general level of skill and knowledge necessary to repair the unit is also increased. The electronics knowledge is generally no greater and often is loss than the mechanical, electrical, optical, or other knowledge characteristic of the occupation but all such knowledge and skill requirements have been increased to cope with the increased complexity and sensitivity of the units. Again, the electronics knowledges are not paramount. The work should be graded in the nonelectronics occupation.

WORK ON ANTENNAS

Positions concerned with antenna repair must be carefully analyzed to determine whether or not electronics knowledge is a paramount requirement. Frequently it is not. Much antenna work is mechanical assembly and repair. This is especially true of antennas in the UHF region and up. These antennas are composed of reflectors, waveguides and, frequently, electromechanical pedestals and drive mechanisms. Knowledge of waveguide theory and electromagnetic propagation are useful but frequently are not as important as knowledge of gear trains, metal working and ability to assemble parts to close tolerances.

Another aspect of antenna repair shows up with antennas designed for low frequencies, VLF through HF particularly. Half wave, long wire, rhombic and a number of other antenna configurations used at these frequencies consist of wire and insulators suspended from poles. The paramount knowledges needed for this work are erecting poles, installation and maintenance of high voltage wiring, etc., which are found in the Electrical Installation and Maintenance Family, 2800.

Knowledge of radiation patterns, electronic testing of voltage standing wave ratios, and adjustments to bring about improvements are specialized portions of the body of electronics knowledge and skill. They are useful but not paramount for most antenna installation and repair positions, other than in some final test and calibration assignments.

WORK ON FIRE ALARM AND SECURITY SYSTEMS

Traditionally, full time work on fire alarm and security systems has been graded in the 2500 Wire Communications Equipment Installation and Maintenance Family. This was a reflection of the electro-mechanical technology used in older systems. Many new systems have adopted electronic technology to increase reliability or veratility. Use of a few solid state amplifiers or switches to update an elecro-mechanical fire alarm system is not sufficient to remove the work from the 2500 Family. The electronic skill and knowledge would be of less difficulty than the electrical and mechanical. Many security systems, however, use closed circuit T.V., radio links, and similar electronic devices. If electronics skills and knowledge are paramount, the work should be graded in the 2600 Family.