# Historical Development of Electric Connectors

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**Synopsis:** This historical development of connectors endeavors to survey briefly the various stages of electric-connector design and the expanding applications of the uses from the earliest types for heavy-duty power applications to the smaller and more intricate fittings in aircraft, electronics, sound equipment, television, and marine applications. Because of the broad scope of the subject, the material is treated in generalizations in order to cover the history within the space limitations of this paper.

It is our belief that connector design, materials, and manufacture are keeping pace with the requirements of new electric equipment. Since the connector is essentially a component part of electric equipment, its development is affected by the requirements of new electric equipment and through adaptations for the improvement of existing equipment is increasing operating efficiencies.

THE primary role of the multicontact electric-cable connector is to disconnect and break electric circuits rapidly. It is also used as a means of switching circuits.

For wiring and servicing operations, the connector simplifies such procedure, compared, for instance, to the slow disconnection details of the screw-type terminal block. With the connector, the danger of rewiring incorrect circuits is also eliminated. The speed with which circuits can be disconnected or connected in emergencies points to another advantage as a safety factor.

In one instance, operating efficiencies of electric connectors were demonstrated in the nine hours per engine time saved in servicing and overhauling a large transport airplane.

Inasmuch as the term "plug" is often used indiscriminately to describe both receptacle and plug, it is well to define the complete connector and its two main parts. The complete connector comprises both receptacle and plug. The receptacle is that part of a complete connector which is normally "fixed," that is, rigidly attached to or an integral part of a supporting surface. The plug is that part of the complete connector which is normally removable after disengagement. Either plug or receptacle may be provided with socket or pin-contact insert assemblies. The type *AN*3101, however, is an exception to the rule.

The choice of a type letter has, for the most part, been variously adopted, depending upon the general use or even—as in the case of type *F* (Figure 1)—for the company, Fox Motion Picture Studios, for whom it was designed. Fortunately, when the Army and Navy specifications connectors were created, a standardized system of nomenclature of parts as well as types was adopted, for which the engineering profession can well be proud.

The precursor to the electric connectors as modified and improved for aircraft applications is found among those early connectors built by James H. Cannon and associates shortly after 1920. The first of these is termed the *M*1–4. It is still in use today and far from obsolescence. It was designated as type *M*, because it was designed for electric motors, 1 because it was the first of a series, and 4 for the number of contacts in the insert assembly.

Compared with the average connectors in use today in aircraft applications, Cannon type *M* (Figure 2) is oversize. Its shell, however, like aircraft connectors today, is aluminum. The inserts were fabricated of laminated phenolics, one having floating female or socket contacts with tapered bores and the mating insert having fixed split male or pin contacts which assumed the angle of the tapered bore sockets upon insertion. Even this pioneer design did not differ greatly from the aircraft connector of today.

Coupling was maintained only by the wedging action of pin and socket con-

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to 40,000 feet, the following characteristics were observed: less load-carrying ability, substantially the same armature-winding temperature, and higher temperatures of bearings. Enclosing an open motor has a similar effect.

The effectiveness of thermal protection is shown by the fact that, over the entire range of conditions tested, including the three motor-thermostat combinations, the armature-winding temperature was held between the limits of 147 and 196 degrees centigrade. Exclusive of locked-rotor tests, the armature-winding temperature was held by the thermostat, under all conditions, between the narrower limits of 166 to 186 degrees centigrade. These figures are well above the range of temperatures which are encountered in any properly applied aircraft motor under any normal conditions. Hence the thermostat will trip only when abnormal conditions are encountered. But the temperatures permitted by the thermostat are low enough to permit a life of a day or more under abnormal conditions.

In the author's opinion, the temperatures for which the thermostats were set are a reasonable compromise. Appreciably lower values might result in nuisance trip-outs, as unnecessary as they might be dangerous. Use of higher temperatures might possibly be justified on the grounds that a minimum of one day's life is unnecessary, but it should be pointed out that maximum horsepower output of a motor decreases with the temperature. Furthermore, some allowance must be made for variations in individual motors and individual thermostats. Also, there are other parts of the motor which can be damaged by excessive temperature, including: bearings, brushholders, shunts, and so forth.

Results comparable to those reported in this paper are to be expected only if skill and care are used in the application of the thermostat. But when this is done, inherent overheating protection is afforded against all abnormal operating conditions, without danger of preventing the motor from performing its normal functions. Thus motor burnouts and consequent replacement can be prevented by thermal protection.

## References

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tacts; yet this proved satisfactory for the applications. This is in contrast to later developments which introduced types with latch-locking devices providing a quick and positive means of coupling, threaded coupling nuts, and also coupling nuts augmented with provisions for safety wire, which presented a more satisfactory means of overcoming problems of weatherproofing and vibration.

In this early type-*M* connector, floating sockets were used. This method of mounting the socket contacts has remained a fundamental standard.

When sound motion pictures went into production in the late '20's type-*M* connectors were used for certain electric circuits, including synchronous camera motors, microphone circuits, and camera blimps, although later type-*M* connectors were exchanged for smaller and lighter fittings in many cases.

Following the type *M*1, came the *M*2, with a three-inch insert diameter having a greater number of contacts. Next came the *M*3 (Figure 2) with an insert diameter of $4\frac{9}{16}$ inches. Type M1 carried contacts for 30-ampere service, *M*2 for 30- and 60-ampere service, and *M*3 from 30- to 90-ampere service.

As can be readily seen, the trend to larger connectors carrying a greater number of circuits in the same general design reached a point of diminishing utility. For example, the *M*3-26 (Figure 3) plug weighed $3\frac{1}{2}$ pounds. Compare this to an *AN* plug with 30 similar contacts weighing 0.336 pound. Variations of the *M* fittings were made, having up to 30 circuits.

However, it was also apparent that the smaller connector would have a wider variety of uses. This opportunity came in 1925, when a certain connector failed to meet a motion-picture sound studio's requirements both in socket design and delivery. An emergency had arisen. However, within a few days, samples were submitted embodying a newly designed socket machined from one-quarter-inch-square brass rod, having a leaf-type contact spring riveted to one side. Cable clamps were cast onto the brass end bell. Pins were pressed into laminated phenolic inserts. Sockets used were the standard full-floating type, which also enabled the sound engineers to avoid variations in contact resistance when the fittings were moved during recording.

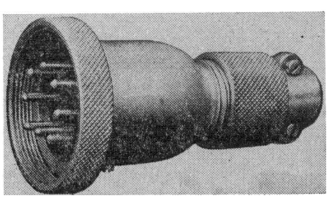

**Figure 1. Type-*F* plug, straight-type, with pin insert assembly and cable clamp**

Thus the type-*F* Cannon connector was conceived and born, with *F* for Fox Motion Picture Studios as a constant reminder of its motive origin. The *F* type proved successful and soon became the standard connector, not only for cinema sound-production equipment, but in many radio stations.

Actually, it was this type *F* that caught the interest of aircraft and airline engineers, beginning the aircraft phase of connectors. But, in the meantime, to be chronologically correct, the type *P* (Figure 3)—*P* for Paramount Studios—was designed, representing the trend toward smaller and more compact connectors. Type *P* had an insert diameter of one inch, a latch-coupling device, a die-cast shell, and molded inserts. These represented definite advances in design and materials which were reflected in connectors built a number of years later. Type *O*—O for oval design—soon followed type *P* and was designed for the inductor-type microphone.

All during these years the aircraft industry was growing, if slowly, and, with the increasing circuits and new service problems, connectors were soon or later bound to be used. The opportunity came one day late in 1932, when James H. Cannon showed a type-*F* connector to Warren Boughton, chief electrical engineer at Douglas Aircraft Company. At this time the *DC*-1 transport ship was in the blueprint stage. Mr. Boughton believed the type-*F* connector to be adaptable to aircraft requirements. Modifications subsequently were made and accepted. Transcontinental and Western Airlines specified it for use on their new airliners to be built by the Douglas Company.

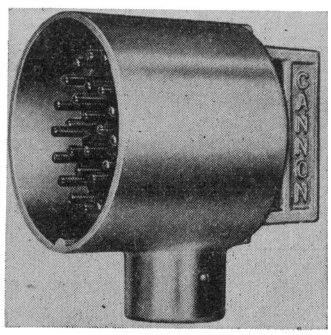


**Figure 2. Type-*M*3 90-degree-angle plug, with pin insert assembly**

The shell material of the *F* was changed from brass to aluminum, and type *F* became *AF* (Figure 4), *A* for aircraft, and the transition from sound equipment to aircraft was complete.

For use on the type *DC*-2 transport airplane in 1933, the cable clamp entrance on the *AF* connector was eliminated, and threads were put on the cable entrance of the shells to permit the use of flexible conduit. At the same time, requirements for additional contacts made it necessary to increase the number of insert arrangements.

The use of connectors increased the safety of aircraft electric circuits and cut down servicing time by many hours, and maintenance of electric circuits was greatly simplified, resulting in labor and time-saving factors. Although numerous developments have been made since that time, these three basic features of electric connectors seldom have varied and remain essentially the same today.

Following closely upon the *AF*, type *FM* (Figure 5) was developed, having a two-inch insert diameter to meet new requirements of aircraft and the concomitant need for more contacts and greater clearance between contacts. Otherwise, the *FM* was identical to the type *F*.

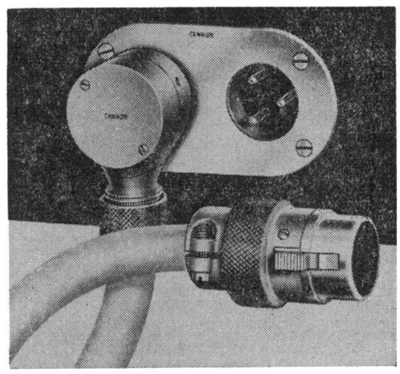

**Figure 3. Type-*P* straight cord plug, with socket insert assembly, lower right. Type-*P* 90-degree-angle plug shown upper left engaged in type-*P* two-gang panel receptacle, flush-mounting, with pin insert assemblies**

The continued demand for lighter and smaller connectors used in many applications such as aircraft fire-wall connections, radio transmitters, radio control panels, tachometers, resistance thermometers, gauge indicators, remote-control thermostats, pumps, various small motors, lights, and governors, resulted in the design of the type *K*, (Figure 6), the first connector series to be designed specifically for airborne equipment. The *K* series was built in eight basic shell sizes, with inserts containing from one to 100 contacts, and in a wide variety of contact sizes, voltage spacings, and amperage ratings. Type *K* represented a marked achievement in the design of electric connectors.

In the type *K*, socket contacts were made from round rod stock, as this type of construction provided a means of grouping more contacts within a limited insert area. Thus, mechanical spacing was reduced with no loss in creepage between contacts. The insulators were fabricated out of sheet phenolic, although during the later development of type *K* molded insulators were used in conjunction with the fabricated type. Shell parts were made of aluminum alloy. Coupling was maintained with a coupling nut having a modified Acme thread, which provided a rapid means of coupling. An exception was the large *AK* size (Figure 6) which used the conventional *NF* thread. On the *AK*, the screw-jack action of the coupling nut was necessary to engage and disengage the fitting, because of the force required to engage and disengage fittings having a large number of contacts.

The smallest type *K* has an insert diameter of five-eighths inch, and the largest, $2^{1}/_{4}$ inches. Type-*K* shell styles

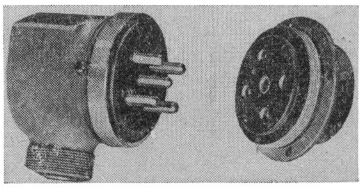

**Figure 4. Type-*AF* 90-degree-angle plug, with pin insert assembly, and opposite, type-*AF* wall-mounting receptacle, with socket insert assembly**

were available in straight, 90-degree-angle, and wall-mounting types, including a special end bell having an integral clamp if required, and accessory fittings included dust caps, dummy, or stowage receptacles, and 90-degree-angle and straight junction shells. Cable entries in the *K* are of two types, taper and straight, with three available conduit threads in several sizes: *B* for Breeze-type thread, once standard for the United States Navy, *AC* for Air Corps and the new *AN* standard.

In 1936, a move to merge the divergent specifications of the Army Air Forces and the Navy Bureau of Aeronautics into one standard was begun for the sake of efficiency and economy. This new Army–Navy specifications on electric connectors was known as *AN*-9534. Since that time, a second specification, *AN-W-C*-591, has been drawn up, with an amended specification pending. The original *AN*-9534, issued November 1, 1939, covered 18 basic shell sizes in five different types: *AN*3100 (wall-mounting), *AN*3102 (box-mounting), *AN*3106 (straight), *AN*3108 (90-degree-angle), and type *RC* (integral-mounting). At that time 53 insert arrangements were available, whereas the total now exceeds 250.

For the type *AN*3102, see Figure 7 and Figure 8; type *AN*3106, Figure 9 and Figure 10; type *AN*3108, Figure 11.

It should be noted that type-*RC* integral mounting was intended for use where the shell of the receptacle is made an integral part of the electric equipment housing.

*AN*-9534 SPECIFICATION:*

*A*. Plug and receptacle, with the exception of receptacle type *RC*, were to be interchangeable between their respective plug and receptacle shells, which applied to each manufacturer's own product and did not require the inserts made by one manufacturer to fit any other manufacturer's plug or receptacle shells.

*B*. Contacts were made from material of high-grade conductivity. Contacts silver-plated, except those made of thermocouple material.

*C*. Interior face of solder cups completely tinned.

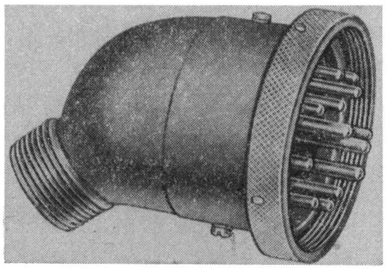

**Figure 5. Type-*FM* 45-degree-angle plug, with pin insert assembly**

*D*. Pin and socket contacts sizes 0, 4, and 8 were designed so that they could be readily removed from their inserts for soldering to conductors and easily assembled after the soldered connection was made.

*E*. Potential millivolt drop not to exceed 7 to 12 on contact sizes 20 to 0, with a range of current from 5 to 200 amperes, between each contact and other contacts and shell.

*F*. Separating force ranged from two pounds on size—20 contact to 20 pounds on number—0 contact.

*G*. Four service ratings—instrument (peak voltage of 70); 24 volts (peak, 100); 110 volts (peak, 350); and 500 volts (peak, 1,000).

*H*. Allowable creepage was based on service for which insert was designed; namely, $^{1}/_{16}$ inch on instrument, $^{1}/_{8}$ inch on 24 volts, $^{3}/_{16}$ inch on 110 volts, and $^{1}/_{4}$ inch on 500 volts.

*I*. Three positioning inserts made possible three distinct polarizations, numbers 1, 2, and 3, by rotating insert in shell. Thus, three identical inserts placed side by side would have distinctly different polarization.

*J*. Plugs were of such construction that it would be possible to install a plug on both ends of a conduit assembly without excessive slack in the conductors within the conduit. To meet these requirements, Cannon designed an end bell which was split in half so that both halves could be removed to provide ample space for servicing.

*K*. Shells and receptacle fittings were made of high-grade aluminum alloys.

*L*. Phenolic materials were used in insert assemblies.

* Adapted from the Army–Navy specifications.

The amended *AN*9534a specification, issued in December 1941, superseding *AN*9534, contained the following main changes:

*A*. Requirements for three positions of inserts were removed, and only position 1 was retained.

*B*. Original specifications provided for the maximum operating voltages for direct current and alternating current under the various service designations. Under the amended specification *AN*9534*a*, the a-c maximum was removed and the d-c table retained. However, reference to alternating current or direct current was removed.

*C*. The number of insert arrangements was increased to 87.

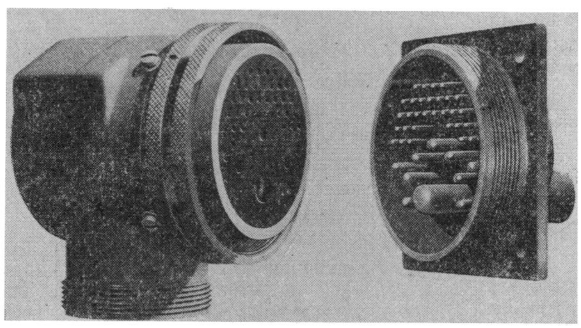

**Figure 6. Type *K* (*AK* shell size shown with *NF* thread on coupling nut)**

Left, 90-degree-angle plug with socket insert assembly. Right, wall-mounting receptacle with pin insert assembly

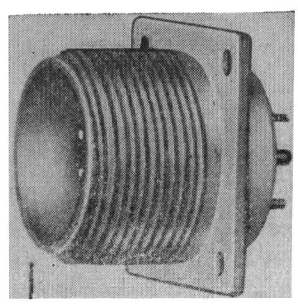

**Figure 7. Type-*AN* 3102 receptacle with pin insert assembly**

*D*. Type-*RC* receptacle was assigned drawing number *AND*10066.

The new specification *AN-W-C*-591, issued in December 1941, which became effective June 1942, carried the bulk of *AN*9534a as well as *AN*9534, with the following changes:

*A*. Deletion of markings of instrument, 24 volt, 110 volt, and 500 volt, from the face of the insulator. Instrument, 24 volt, and 110 volt were grouped under service *A*, 500 volt under service *B*, and such high voltages as 14,000 under service *C*.

*B*. Since military aircraft, in particular, was seeking higher altitudes, effective creepage distances were increased. Service *A* with a peak voltage of 200 required one-eighth-inch minimum creepage distance; service *B* with a peak voltage of 750, $^5/_{16}$ inch; and service *C*, 14,000 volts, one inch. To maintain the interchangeability of inserts and also retain the mechanical spacing, but increase the effective creepage distance, it was necessary to design barriers on the face of the inserts.

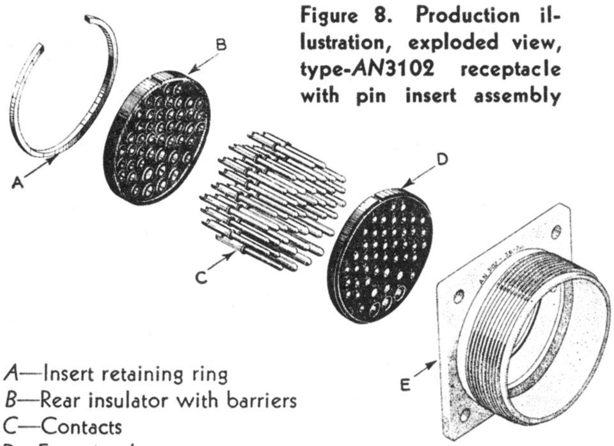


**Figure 8. Production illustration, exploded view, type-*AN*3102 receptacle with pin insert assembly**

*A*—Insert retaining ring
*B*—Rear insulator with barriers
*C*—Contacts
*D*—Front insulator
*E*—Shell

*C*. Shell sizes 44 and 48 were eliminated from the new specification.

*D*. Type-*RC* integral mounting was issued a number series for shell sizes, *AND*10425 to *AND*10436.

The newest *AN* connector is type *AN*3101 which, like the *AN*3106 and *AN*3108, embodies the portable features of a plug, but is not a fixed mounting like types *AN*3102 or *AN*3100. However, type *AN*3101 has the threaded cable entry of a receptacle. This new type is being made in sizes 8*S* to 40 inclusive, under the proposed *AN-W-C*-591*a* specification. Another new *AN* type under this specification is the *AN*3017, quick-disconnect fitting, which is restricted to sizes 8*S* to 20.

Among other connectors which are used in one way or another on aircraft or other war material which are of considerable importance but rather specialized in application, are the type *DP* and battery connectors, both developed within the last four or five years.

The *DP* is best generally described as rectangular in shape. *DP*'s are particularly adapted to rack-mounted radio and range-finding equipment. Several *DP* types mount directly to the outside face of the chassis itself, alignment being effected by a taper in the shell and by the contact arrangement itself. Coaxial contacts for radio antennas are standard in several of the *DP* fittings. Contacts vary from 10 to 135, the largest connector in the series being type *DPL* used for special equipment by the Army Air Corps.

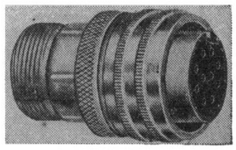

**Figure 9. Type-*AN*-3106 plug, with socket insert assembly**

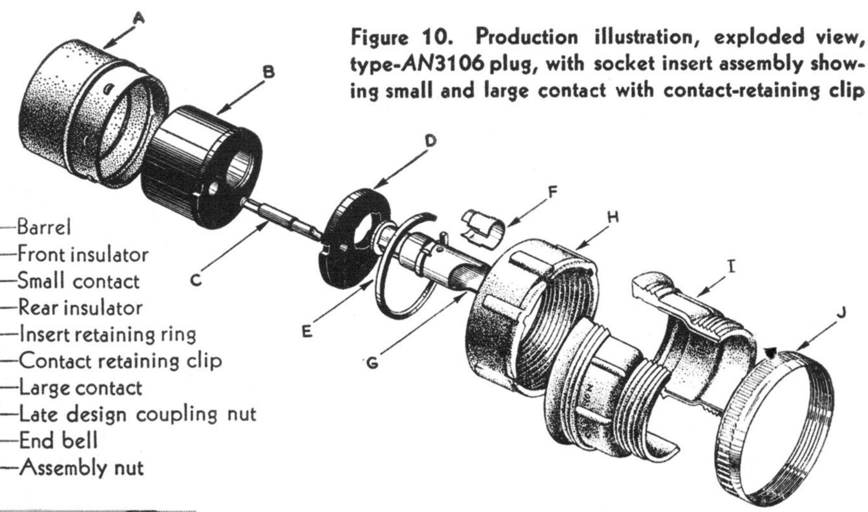


**Figure 10. Production illustration, exploded view, type-*AN*3106 plug, with socket insert assembly showing small and large contact with contact-retaining clip**

*A*—Barrel
*B*—Front insulator
*C*—Small contact
*D*—Rear insulator
*E*—Insert retaining ring
*F*—Contact retaining clip
*G*—Large contact
*H*—Late design coupling nut
*I*—End bell
*J*—Assembly nut

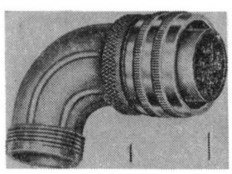

**Figure 11. Type-*AN*3108 90-degree-angle plug with socket insert assembly**

A notable development of the line of battery connectors, which have been in use for a number of years in engine starting and other applications, is the type numbered 11,749 and 11,751, which was developed at the request of the Air Corps to facilitate disconnection of batteries, particularly in extremely cold climates. The design formerly in use required the maintenance mechanic to loosen two small wing nuts before removing the battery, a slow and difficult process in subzero weather. During removal, the battery contacts were likely to strike the aluminum side of the air frame, creating a short circuit and consequent fire hazard, whereas this new development completely encloses the contacts. In addition, it has a handwheel for disconnection, which can easily be turned with a gloved hand.

The materials in the insert insulators constantly are being improved to overcome high-altitude problems, humidity, and fungus growths of tropical climates, and circumstances of salt-water conditions. Research in thermoplastics, thermosetting materials, and protective coatings is going forward rapidly.

Briefly, among the other developments which are yet to be recorded in the chapters on the history of electric connectors are snap-in solderless contacts. Still other new developments not entirely out of the experimental stages include the following: connectors having a greater voltage for high cycle; special switching devices which operate engine-starting units; and waterproof designs for marine and ordnance requirements.