Advances of a generation ago, such as rubber compounding, look like minor changes when stacked up against developments in insulation and coverings made in the last 10 years.

Synthetic Rubbers. *During World War II, natural rubber* dropped out, and synthetics substituted. In but a few years, both cable makers and power engineers found many factors favoring the new synthetics. So many, in fact, that natural rubber is now disappearing as a wire and cable insulation.

Heat is the great accepted enemy of insulations. But the "cold" rubber in today's type R does a good job of resisting heat compared to type R of some years back. Going further still is type RH-RW; although a little more costly, it's being used enough to materially affect sales of type R.

Ozone-resistant butyl-base compound is another excellent performer. It's today's dependable compound for voltages to 15 kv, and often higher, offering stability, slow aging, low pf, other desirable physical and electrical characteristics.

Neoprene jacketing for rubber-insulated cables is making big strides. Relatively inexpensive, it's dependable under many tough conditions in moist or dry conduit, in earth, or in aerial runs. Silicone rubber is another newcomer. Its resistance to heat, many oils, solvents and other chemicals makes it suitable for some process-plant applications.

Thermoplastics. You can do a wiring job in your plant today using only materials that barely existed in 1940 – typical are the thermoplastics, polyvinyl chloride and polyethylene.

Polyvinyl chloride – pvc for short – fits a wide range of applications. It resists oils, acids, alkalis, greases, gasoline, moisture, abrasion. With normal treatment and protection it offers long life. We've mentioned but a few of the thermoplastics. The list has grown long in recent years: Rulan, Nylon, Cordolite, Saran, Tenite II, Styraloy, Teflon.

typical modern cable insulations temperature and voltage limits

insulation, type	recommended max size, awg or mcm: single conductor	multi conductor	maximum ratings: copper temp, C	voltage
thermoplastic				
type T, TW	2000		60	600
polyethylene	4/0		80	5000
"thermoplastic" NEC	4/0		60-105	600
thermosetting				
type R, RW	2000	750	60	5000
type RH	2000	750	75	5000
type RU	?		60	600
performance	2000	1000	60	
ozone-resistant	2000	750	75	8000
AI-asbestos				35,000
type A	8		200	300
type AA	4/0		200	300
type AI	6		125	300
type AIA	1000		125	600
asbestos-varnished-cambric				
types AVA, AVL	1000	500	100-110	5000
type AVB	1000	500	90	5000
varnished cambric				
shielded	1500	1000	70-85	28,000
nonshielded	2500	1000	70-85	15,000
impregnated paper, solid				
1/c nonshielded	2500		60-85	75,000
3/c shielded	—	1000	65-85	45,000
3/c nonshielded	—	1000	75-85	15,000

Logically, thermoplastics replace rubber for some applications, but not all. Toughness of thermoplastics permits use without protective *braid. This factor alone means* smaller over-all diameter, less space needed in conduit. In modernization programs where existing conduits are reused, more copper can be pulled in, an important consideration when rewiring commercial and institutional buildings.

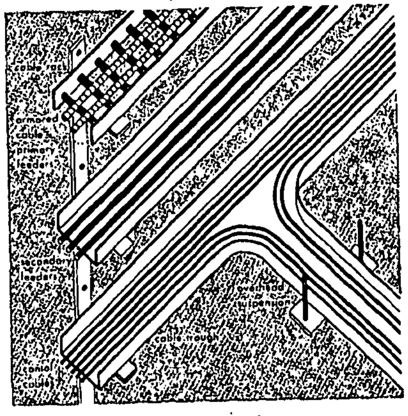
Rigid conduit has been the backbone of industrial wiring systems for generations. In the days of lower labor costs, necessary threading, cutting and bending wasn't as critical. And there was no substitute that offered *all the advantages* of conduit: top mechanical protection, good electrical conductivity (important for neutral grounding).

Thinwall Conduit. During the 1930's, thinwall conduit began cutting its teeth in industrial plants. It offered light weight, easier cutting and, of greater value, no threading. Compression couplings and terminal fittings, slipped over the new conduit, permitted installation with only hand tools. Bending became an easier job with tools designed to handle the thinner tubing (POWER, May 1953, pp 128, 129).

Trays and Ducts. Thinwall was just the beginning of a concentrated effort to find low-cost easily installed raceways. Trays and ducts have *and will continue to be used*, especially where many wires or cables are to be carried in the same general area. Typical would be control wiring and low-voltage secondary feeders. Trays are available prefabricated, complete with fittings to dodge around obstructions. Their big feature is ability to carry many wires and cables in the one raceway. And when future additions call for more, it's a simple matter to lay the needed additions in place, if ample space was provided in original design. Today's trays are generally made of expanded metal for lightness.

The self-contained wiring systems (interlocked-armor and mineral-insulated copper-sheathed) fit into this move to develop low-cost *enclosed wiring systems*.

Where trays and racks are used in place of conduit, general practice today dictates keeping primary, secondary and control cables segregated. A typical arrangement is sketched, right. Note the ladder-like rack serving as support for the high-voltage primary feeders of the interlocked-armor type.



Is rigid conduit out as a *raceway* in industrial plants? Far from it. Where top mechanical protection is needed, there is no substitute for heavy-wall rigid conduit. *But where number* of cables required calls for running a large number of conduits, and where degree of protection offered by conduit isn't needed, trays and ducts are a likely answer.

After mastering basic differences between aluminum and copper engineers find more uses for light, corrosion-resistant metal

Aluminum is working its way into plants as an electrical conductor. It is growing in importance as cost of aluminum continues to drop. In time it will find its proper spot; but copper is, and will remain, the No. 1 conductor.

There's nothing really new about all this. Back in 1898, the light metal was installed as a bus conductor in the 600-v 60,000-amp bus at Niagara Works. Aluminum tubular conductors for outdoor switching stations followed. Here it offered resistance to weathering and longer permissible span lengths. It also found application in the chemical industry where copper corrosion was a *problem*. Aluminum has seen service in plating rooms where sulphuric-acid, cyanide and cadmium-oxide fumes are present.

Where It Fits. Aluminum has natural advantages fitting it for several spots in the industrial system. For overhead installations, light weight per amp is a major factor. The fact that larger diameter is needed than for copper proves of little importance overhead since no conduit is used. Another natural is buswork *in primary substations*. But to find suitable applications in your plant calls for an engineering study weighing all facts.

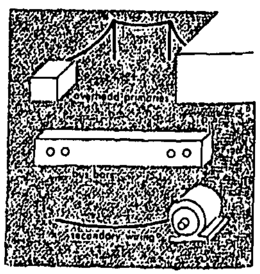
There's less advantage in going to aluminum for smaller conductors. By small we mean about No. 6 or less. In this range, weight advantage is little and greater number of *connections may* quickly cancel out any other advantages. Connecting aluminum has been a problem. At present most field troubles crop up because electricians and even some design engineers, fail to get more than a nodding acquaintance with the "how-to" side of aluminum as a conductor in wiring systems.

Aluminum Is Different. When aluminum building wire bowed in shortly after the last war, its hard-drawn finish gave it an undesirable "springy" quality. But an intermediate temper was adopted that gave better handling qualities. This change in tempering also improved "nickability"—breaking off if accidentally nicked by the knife when insulation is skinned.

But there still are basic differences between aluminum and copper. Size is one. Copper is a better conductor; aluminum is about 61% as conductive for any given wire diameter. This factor alone generally dictates larger conduits for aluminum. And there's where an aluminum installation can go *off* base.

You can't decide, after conduit runs are laid out, and perhaps installed, that aluminum would be a good bet in some part of the system. Aluminum must be designed as a system: it needs its own *connectors, larger* boxes and conduit.

Aluminum Oxide. When aluminum is exposed to air, an oxide forms. A poor conductor, it can be scraped off but reforms immediately. Today's procedure coats cable with one of several available compounds; oxide is then removed, usually with a wire brush. Cable end, compound and all, is put into connector. With compression-type connectors, pressure rubs oxide film off cable strands. Since all air is squeezed out of joint, insulating oxide film doesn't get a chance to reform. Result: A good electrical connection between strands in cable and between *cable surface and connector*.



Electrolytic Action. This is another factor to consider when joining aluminum and copper where moisture is present. A miniature electric cell can be set up and one of the metals, aluminum, will be eaten away. Solution appears to be use of tin-plated aluminum lugs. Place aluminum above copper so copper salts formed will flow away from joint.

Aluminum has a higher creep rate than copper. That's why connectors for aluminum have more surface—to reduce pressure on conductors in joint yet keep them from working loose.

Thermal expansion differences between copper and aluminum must also be taken into account. Aluminum's coefficient of expansion is about 38% greater than copper's. Thus, usual run of copper connectors are not suitable. For a good joint, connector must be designed to handle the differences in rate of expansion of the two metals.

Making Joints. In addition to the facts outlined above, remember that joints can also be made with standard heat methods. Aluminum solder, used with suitable flux and torch, will turn out a satisfactory aluminum-to-aluminum joint. On a large job, calling for many joints, consider use of argon-arc welding and aluminum terminals. No flux is needed. Resultant weld is clean, completely conductive, free of inclusions.

Bolted or compression fittings often give a faster and more reliable joint. Bolted fittings cut down installation time and require few tools. If made of copper or copper alloy, they are coated to protect against electrolysis.

Compression Fittings. These have been used for over 40 years, primarily on overhead aluminum transmission lines. Now similar fittings are available for use on insulated wire and cable. Special tools that exert heavy pressure are used for application. Pressure compresses body of fitting around the cable, forming a deep indent. Cross-sections of compression joints show that cable strands in the fitting have been packed into practically a solid mass. Wiping action of metal during compression breaks the oxide film, yielding low electrical resistance. Whether bolted or compression fittings are employed, however, good practice calls for a suitable compound to maintain a good joint.

All things considered, aluminum as a conductor in the industrial plant is here and will remain. Manufacturers anxious to exploit aluminum's advantages have largely overcome the space and connector problems in their equipment. Plant electricians *like aluminum* because of its lighter weight. But you'll have to keep close tabs on them until they become familiar with using it, and they'll have to pay attention to details of good practice.

When you buy equipment, tell the manufacturer whether you plan to use aluminum with it. Otherwise it may be delivered to you with copper connectors, probably unsuited for aluminum.