Industrial applications of dc grow, not only among past big users like steel and aluminum but also in general. Reason: To meet needs for degrees of speed variation to be had only in dc motors.

Recent thinking favors a number of dc conversion points close to load centers, with short dc secondaries, *instead of central conversion*. And equipment follows the modern "packaged" theme. For sizeable applications, the package is a *full-fledged unit substation*, with an ac circuit breaker, step-down transformer, dc conversion unit, dc main breaker and smaller dc feeder breakers.

Static rectifiers, with high over-all efficiency and low maintenance, get the call for many of today's jobs. In steel mills, for example, mercury-arc units are major source of 250-v dc and also appear to be *taking over on main drives of continuous mills*. But where reversing and variable speed are needed, as on blooming mills, mg sets still serve best.

Four basic conversion units outlined below have their special virtues but there are areas of "overlap" — where more than one will do the job reasonably well.

Selection. First consider load "geometry" and then its electrical characteristics: voltage, current, etc. Need for widely variable voltage might point to an mg set. A *heavily fluctuating load* with frequent severe overloads might favor rectifiers. So would sizeable periods of no load or light loads; rectifiers have relatively low no-load and partial-load losses.

Be sure to consider *ambient conditions, space requirements*, and those ever-present factors — first cost and operating cost.

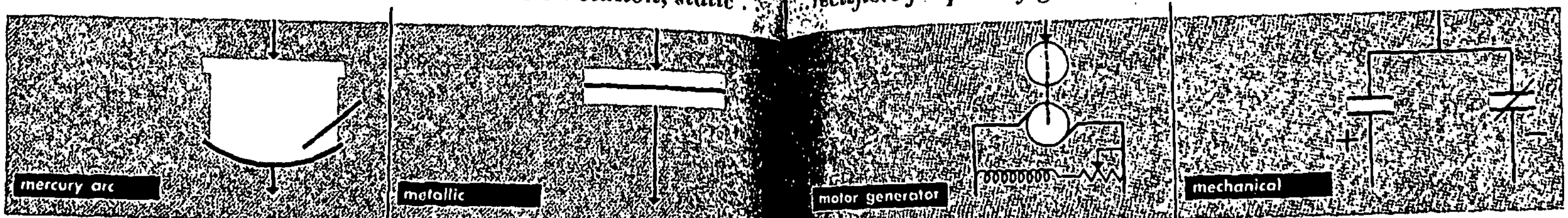
Essential Services. In reduction of manganese, power outages of more than a few seconds can't be tolerated. While not necessarily this critical, many other dc services must be protected against interruption. Possible answers: (1) separate ac feeds (2) duplicate conversion equipment. Both also help during scheduled maintenance shutdown. But what if economics won't justify cost of additional units? Then use single-pole high-speed anode switching to isolate individual tanks or tubes of mercury-arc unit. This keeps it on line in spite of an arcback or failure in one tank.

Magnetic amplifiers are coming into conversion picture, particularly above 600 v. A small unit can provide an output proportional to dc current, hence measure it without taking high-voltage dc to the board. Similar idea can be used for volts, watts, watthours.

How rectifiers work

Look on today's rectifiers as *selective electric valves*. They allow only the positive portion of an ac wave to flow through to the positive side of the dc bus. The negative wave is either completely blocked (half-wave rectification) or fed to the negative dc bus (full-wave *rectification*). The full-wave rectifier thus uses both sides of the incoming ac voltage wave.

In today's load-center-located ac-dc conversion station, static rectifiers frequently get the nod, but mg sets are still important



Before 1937, all commercial mercury-arc rectifiers were of multi-anode type, with 6, 12, or 18 anodes per tank. Coming of the more-efficient single-anode type (*first the ignitron, then the excitron*) *broadened applications in lower voltage range* — 200 to 300 v. The pumpless tube pushed practical usefulness to still *lower ratings*.

Ignitron's *distinguishing feature is a small stationary electrode* immersed in cathode mercury pool. This ignitor starts the *cathode spot*. Once established at *mercury surface*, main anode can pick it up and conduct in one direction.

Method of creating cathode spot differs in the excitron. While rectifier operates, a pilot arc *from the excitation anode* continuously maintains spot on the mercury surface.

Basic elements of any metallic rectifier are a good conductor and *a poor one (semi-conductor)*, with a barrier layer. Current flows more readily from semi-conductor to good one.

Advantages are: *ruggedness*, no *filament excitation*, no time delay, long life, high efficiency. But metallics are likely to cost more than tubes, show poorer voltage regulation and *lower efficiency at high voltages. They lack grid control*, weigh more, take up more space.

Today's metallics include magnesium-copper *sulfide*, copper sulfide, copper-oxide, selenium. Germanium, a newcomer, is now available in units rated *to* 25 kw at 125 v. Metallic *rectifiers find use in battery charging, resistance* welding. They supply dc for small motor loads in increasing number.

In spite *of advances* in the *rectifier* art, and growing application of static units, mg sets still handle a good bulk of the load. Big reason: An mg set *can* deliver anywhere from zero to maximum voltage. In general, voltage variation is obtained by changing field strength of generator. *Any reasonable* voltage can be had by taking advantage of the characteristics of shunt, over- or under-compounded connections.

Ambient conditions — *temperature*, dust, humidity, hazardous atmospheres — are important for mg sets. Temperature by itself is a limiting factor in insulation life, but *modern* insulations (p 42) *have this licked*; Class H to 180C. Various types of enclosures (pp 40, 41) cope with problems of water, hazardous atmospheres and explosive conditions.

Mechanical rectification was introduced in this country just after World War II, and there are still only a limited number of units in operation. The rectifying element *is a set of* metallic contacts driven by a synchronous motor. These close when ac sine wave is in desired direction, break contact when ac voltage reverses. In other words, it is a motor-driven switch, *connecting* and disconnecting ac and dc systems in synchronism with sinusoidal variation of *ac*.

Major problem *is to open* and close contacts only when ac wave is passing through zero, to minimize wear on contacts. This is now done by using a *saturable* or "commutating" *reactor* inserted between transformer terminals and ac bus. This stretches the zero-current time of the ac wave.

Sealed or pumpless mercury arcs gain wide acceptance for small, medium loads

Simple, reliable and easy to maintain, sealed or pumpless mercury-arc units are gaining wide acceptance on small to medium loads (750-1000 kw).

Typical unit in metal-enclosed cubicle *comprises a number of sealed tubes or* tanks, associated excitation equipment and accessories. Tubes are evacuated, degassed and sealed at the factory. This eliminates vacuum connections, *equipment for maintaining and indicating vacuum*, cuts maintenance.

Tubes are water cooled. After passing through tank jackets, water goes to a heat exchanger before recirculation. Raw water flowing through exchanger to drain carries away the heat. Direct cooling by raw-water supply is also employed. Where water is scarce, *water-to-air exchangers* can be used.

Performance. How long do tubes last? Roughly *five to seven years if* properly applied and operated. Manufacturers generally guarantee for two years on *a prorata adjustment basis*.

In general, the sealed mercury-arc rectifier will now show about 7% better full-load efficiency than an mg set. This will vary to approximately 19% at quarter load on 600-v service. For 250-v service, efficiency curves *still show* a strong advantage *for* mercury-arc units compared to mg sets.

But *pumpless mercury* units have inherently lagging pf. In contrast, an mg set boasts pf between unity and 80% leading. Watch this if your utility contract has a pf penalty clause. At full load *and rated* voltage, a pumpless rectifier will run about 87% lagging. A bank of capacitors (230 kvar for 1000 kw) would raise this to 95%.

With top efficiency promised, development of mechanical rectifiers goes ahead

Efficiency is the big reason industry watches development of *mechanical* rectifiers. Values of 94 to 97% (over-all, ac to dc bus) are recorded. This is a major consideration where dc loads are heavy, as in electrochemical plants.

Mechanical units *handle* fluctuating loads between limits but are critical on overload. Normal voltage span of today's units *is* 5- to 400-v dc. Current ranges between 1500 and 10,000 amp; units are paralleled *for larger loads*.

Any *fixed* voltage drop penalizes rectifier efficiency increasingly as voltage is lowered. Mechanical rectifiers have no constant voltage drop anywhere from ac to dc bus. That's a reason *for slanting to applications* under 400 v.

Fine voltage control can be had, with quick response. Two methods are used. One regulates supply voltage with an induction regulator or transformer *tap changer*. Second method, known as phase shift, delays point in ac wave where commutation *starts*. Rotating the stator of the synchronous drive motor does the job. Usual practice changes supply *voltage* for coarse regulation, with phase shift for close adjustment.

Two *limitations* are: (1) Unit can't stand a current reversal to rectifier itself. (2) If ac feed is lost, unit will shut down and some of silver contacts will generally need replacement.

Today's maintenance problems center about the main silver contacts. Available figures peg maintenance at about 1½% of total *rectifier* cost spread over a 5-year period. If the drawback *of* short contact life can be licked, as now seems *indicated*, we'll have another major rectifying device to serve industry.