manganese is added, the steel is very brittle, and the further addition increases this brittleness until the quantity of manganese has reached 4 to 5.5 per cent. when the steel can be pulverized under the hammer. With a further increase, however, of the quantity of manganese, the steel becomes ductile and very hard, reaching its maximum degree of these qualities with 12 per cent. of manganese. The ductility of the steel is brought out by sudden cooling, a process the opposite of that used for carbon steel. These properties of manganese steel make it especially adapted for use in the manufacture of rock--crushing machinery, safes and mine car wheels.

Nickel finds its largest use in the manufacture of special nickel and nickel-chromium steels, and the use of these steels for various purposes in the arts is constantly increasing. The greatest quantity of nickel steel is used in the manufacture of armor plate, either with or without the addition of chromium. There is probably no armor or protective-deck plate made which does not contain from 3 up to 5 per cent. of nickel. Nickel steel is also used for the manufacture of ammunition hoists, communication tubes and turrets on battleships, and for gun shields and armor.

The properties of nickel steel, or nickel-chromium steel, that make it especially adapted for these purposes, are its hardness and great tensile strength, combined with great ductility and a very high limit of elasticity. One of the strongest points in favor of a nickel-steel armor plate is that when it is perforated by a projectile it does not crack. The Krupp steel, which represents in composition about the universal armor-plate steel, contains, approximately, 3.5 per cent. of nickel, 1.5 per cent. of chromium and 0.25 per cent. of carbon.

Another use for nickel steel that is gradually increasing is the manufacture of nickel-steel rails. During 1903 there were over 11,000 tons of these rails manufactured, which were used by the Pennsylvania, the Baltimore & Ohio, the New York Central, the Bessemer & Lake Erie, the Erie, and the Chesapeake & Ohio railroads. These orders for nickel-steel rails resulted from the comparison of nickel-steel and carbon-steel rails in their resistance to wear during the five-months' trial of the nickel-steel rails that were used on the horsehoe curve of the Pennsylvania Railroad. The advantages that are claimed for the nickel-steel rail are its increased resistance to abrasion and its higher elastic limit, which increases the value of the rail as a girder. On sharp curves it has been estimated that a nickel-steel rail will outlast four ordinary rails.

Nickel steel has also been largely adopted for forgings in large engines, particularly marine engines, and it is understood that this is now the standard material for this purpose in the United States navy. There is a very great variety of these forgings and drop forgings which include the axles and certain other parts of automobiles, shafting and crank shafts for Government and merchant-marine engines and stationary engines, for locomotive forgings, the last including axles, connecting rods, piston rods, crank pins, link pins, and pedestal cap bolts, and for sea-water pumps.

Another important application that is being tried with nickel steel is the manufacture of wire cables, and during the last year such cables have been made by the American Steel and Wire Company, but no comparison can as yet be made between them and the ordinary carbon-steel cables with respect to their wearing qualities. In the manufacture of electrical apparatus nickel steel is beginning to be used in considerable quantity. The properties of this steel which make it especially valuable for such uses are, first, its high tensile strength and elastic limit, and second, its high permeability at high inductions. For rock drills and other rock-working machinery nickel steel is used in the manufacture of the forgings, which are subjected to repeated and violent shocks. The nickel content of the steel used in these forgings is approximately 3 per cent., with about 0.40 per cent. of carbon. The rock drills or bits are made for the most part of ordinary crucible cast steel, which has been hardened and tempered. A nickel-chrome steel is now being made, which is used to some extent in the manufacture of tools.

Nickel steel in the form of wire has been used quite extensively and for many purposes—for wet mines, torpedo-defense netting, electric-lamp wire, umbrella wire, corset wire, etc.—where a non-corrosive wire is especially desired. When a low coefficient of expansion is desired—as in the manufacture of armored glass, in the mounting of lenses, mirrors, level tubes, balances for clocks, weighing machines, etc.—nickel steel gives good satisfaction. For special springs, both in the form of wire and flats, a high carbon nickel steel has been introduced to a considerable extent. Nickel steel is also being used in the manufacture of dies and shoes for stamp mills, for cutlery, tableware, harness mountings, etc.

Nickel steels containing from 25 to 30 per cent. nickel are used abroad to some considerable extent for boiler and condenser tubes and are now being introduced into this country. The striking characteristic of these steels is their resistance to corrosion, either by fresh, salt or acid waters, by heat and by superheated steam. In addition to marine boilers, high nickel-steel tubes can be used to advantage for stationary boilers, automobile boilers and locomotive safe ends.

The largest use of chromium is in the manufacture of a ferro-chromium alloy which is used in the manufacture of chrome steel. In the manufacture of armor plate ferro-chrome plays a very important part, and, although it is sometimes used alone for giving hardness and toughness to the armor plate, it is more commonly used in combination with nickel, making a nickel-chromium steel armor plate. Other uses of chrome steel are in connection with five-ply welded chrome steel and iron plates for burglar-proof vaults, safes, etc., and for castings that are to be subjected to unusually severe service, such as battery shoes and dies, wearing plates for stone crushers, etc. A higher chromium steel, which is free from manganese will resist oxidation and the corrosive action of steam, fire, water, etc., to a considerable extent, and these properties make it valuable in the manufacture of boiler tubes. Chromium steel is also used to some extent as a tool steel, but for high-speed tools it is being largely replaced by tungsten steel, which seems to be especially adapted to this purpose.

Ferrochromium is made in an electric furnace and is produced directly from the ore. In the United States the company producing the largest quantity of ferrochromium is the Willson Aluminum Company, whose electric furnaces are located at Kanawha Falls, W. Va. Besides the manufacture of ferrochromium this company also makes ferrotungsten, ferromolybdenum, ferrosilicon, ferrovanadium and ferrotitanium. The company obtains its chief supply of chrome ores from the Daghardi mines, in Asia Minor, and the Thiebargi mines in New Caledonia. Ferrochromium has also been made by the Willson Aluminum Company from the chromium ores from the Black Lake District, Quebec.

The Willson Aluminum Company has been supplying the ferrochromium used by the Bethlehem and the Carnegie steel companies for the armor plates which these companies have manufactured.

The demand for tungsten ores for use in the manufacture of ferrotungsten to be used in the manufacture of tungsten steel continues to increase, especially from abroad. Tungsten steel is used to some extent, more generally abroad than in the United States, in the manufacture of armor plate and armor-piercing projectiles. For this purpose it is used in combination either with nickel or chromium, or with both of these metals. The use for which tungsten steel seeems to be best adapted is in the manufacture of high-speed tools and magnet steels. There is considerable variation of opinion as to the value of tungsten in the manufacture of armor plate.

The use of molybdenum steel continues to increase, and hence there is an increasing demand for the ores of this metal. The main use of ferromolybdenum is in the manufacture of tool steel.

MACHINE SHOP NOTES FROM THE STATES.

By Charles S. Gingrich, M.E.

XIII.

The manufacture of cream separators has grown to be a special industry of considerable proportions, there being a great many large shops devoted entirely to their manufacture. The development of the industry carried with it a great many special tools and processes adapted to these particular requirements.