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Energy Consumption in Domestic Primary Copper Production

UNITED STATES DEPARTMENT OF THE INTERIOR

Information Circular 8698

Energy Consumption in Domestic Primary Copper Production

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Each stage of copper production has been analyzed to determine total energy consumed, energy mix required, cost of the energy, and recent or proposed changes in operations which may affect the consumption of energy by the copper industry. Data have been gathered from a recent Bureau of Mines canvass of the industry, from visits to copper operations, and from conversation with copper industry officials.

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by

Rodney D. Rosenkranz [1]

ABSTRACT

Energy consumption in domestic copper production has increased nearly 60 percent in the last 10 years, reaching approximately 175 trillion Btu in 1973. Energy required to produce 1 pound of copper rose from nearly 41,000 Btu in 1963 to nearly 50,000 Btu in 1973. Production from lower grade ores and strict pollution control regulations have contributed to this increase.

Each stage of copper production has been analyzed to determine total energy consumed, energy mix required, cost of the energy, and recent or proposed changes in operations which may affect the consumption of energy by the copper industry. Data have been gathered from a recent Bureau of Mines canvass of the industry, from visits to copper operations, and from conversations with copper industry officials.

INTRODUCTION

The purpose of this study is to analyze the consumption of energy within the domestic primary copper industry. The mining, beneficiating, smelting, and refining stages of production have been analyzed to determine energy consumed at each stage, the energy mix required, cost of the energy, and recent or proposed changes in operations which may affect the consumption of energy by the copper industry. Where possible, past and current consumption have been compared.

All energy consumption figures in this report, unless specified, reflect averages for copper producers within the United States. All forms of energy have been converted to British thermal unit equivalent.[2] Although some electricity consumed in copper production is derived from hydropower, for comparison purposes in this report it was assumed that all electricity was produced by fossil-fueled plants.

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[1]Economist.

[2]Electricity has been converted to equivalent British thermal unit inputs assuming an average efficiency of 33 percent by fossil-fueled steam-electric plants. Thus, this report has used an average of 10,239 Btu as the energy input required to produce each kilowatt-hour of electricity.

The Bureau of Mines recently conducted a canvass of the copper industry to determine energy consumption in the mining, beneficiating, and smelting stages (appendix B). Canvass results have been combined with data gathered from visits to copper operations and from discussions with copper industry officials. Historical energy consumption data were gathered from the Bureau of the Census (Census of the Mineral Industry and Census of Manufactures), as well as other Government and private or institutional publications.

Bureau of the Census information appears to be the basis for nearly all data found in other publications. Data published by the Bureau of the Census in the past combined mining with beneficiating and smelting with refining. While these data are valuable, the need for additional and more specific data led to the preparation of this report.

BACKGROUND

For purposes of this report, all forms of energy have been converted to British thermal unit equivalent using the factors shown in table 1.

TABLE 1. - Energy conversion factors

	Btu/unit
Electricity....kW-hr..	10,239
Heavy fuel....gallons..	149,690
Diesel or light fuel....do......	138,690
Gasoline....do......	124,952
Other petroleum....do......	131,029
Natural gas....1,000 ft^3..	1,031,000
Coal....short tons..	24,050,000
Coke....do......	26,000,000
Other energy....kW-hr..	10,239

Nearly 40 percent of energy consumption in the United States in recent years has been by the industrial sector. Over 20 percent of this amount has been by primary metal industries. The principal energy consumers within the primary metal sector are aluminum, iron, and copper producers.

Data collected for this study indicate that the energy required to produce a pound of copper has increased over 20 percent since 1963 (table 2). Reasons for this increase include production from lower grade ores and more stringent State and Federal pollution control laws.

In 1963, energy consumed in copper production was approximately 110 trillion Btu. By 1973, energy consumption had increased to about 175 trillion Btu, a yearly growth rate of 4.75 percent. Greater annual copper production has contributed in part to this increase; however, an increase in the energy required to produce each pound of copper has also been a factor.

TABLE 2. - Energy consumed in copper production, 1963 and 1973

	1963	1973
Mining-beneficiation:		
Btu consumed.........................billions..	46,035	87,603
Copper produced.................million pounds..	2,426	3,436
Btu per pound copper...........................	18,973	25,497
Smelting-refining:		
Btu consumed.........................billions..	[1]64,768	87,773
Copper produced.................million pounds..	2,991	3,667
Btu per pound copper...........................	21,654	23,935
Total energy consumed (Btu per pound copper)..	40,627	49,432

[1]Estimated from 1962 data.

Source: Bureau of the Census. Census of the Mineral Industry, 1963; Census of Manufactures, 1963, 1972.
Bureau of Mines. Canvas of Copper Producers 1973; Minerals Yearbook, Copper chapter, 1963, 1973.

Production of copper involves four stages: Mining, beneficiating, smelting, and refining. Table 3 shows the average energy requirements and costs to produce a pound of copper in 1973 for each of these stages. Average energy costs to copper producers are shown in appendix A. Table 4 shows the quantities of energy copper producers consumed, the British thermal unit equivalent of each type of energy, and the estimated energy costs.

TABLE 3. - Average energy consumption and cost for copper production, 1973

	Energy consumed, Btu per pound copper	Energy cost, cents per pound contained copper
Mining:		
Underground mines...........	9,080	1.19
Open pit mines..............	7,255	.78
Average..................	7,560	.86
Beneficiation:		
Flotation..................	18,087	2.46
Leaching and precipitation..	17,373	2.45
Average..................	17,937	2.46
Smelting.....................	17,923	.87
Refining.....................	6,012	.64
Grand total or average...	49,432	4.83

TABLE 4. - Quantity, Btu equivalent, and cost of energy for copper production

	Quantity	Btu, billions.	Cost, thousand dollars
Electricity...........thousand kW-hr..	8,365,633	85,656	121,945
Heavy fuel..........thousand gallons..	54,719	8,191	3,923
Diesel or light fuel.........do........	108,626	15,065	13,297
Gasoline....................do........	6,724	840	1,311
Other petroleum.............do........	702	92	85
Natural gas........million cubic feet..	58,013	59,811	24,894
Coal.............thousand short tons..	184	4,435	2,171
Coke........................do........	46	1,197	1,682
Total[1]...........................		175,377	169,448

[1]Average energy required per pound of copper produced was 49,432 Btu at a cost of $0.0483.

Copper production involves many steps within each of the four stages of production. Figure 1 shows graphically the principal steps involved and estimates the energy required at each step. The data presented in the flow sheet represent average energy consumption based on canvass results and personal communication with industry officials. In some cases, energy consumption varies greatly between companies. Each of the four stages of production is discussed later.

In this report it was assumed that all energy consumed by primary copper mines was for production of copper. Therefore, energy that may have been consumed in byproduct production was included in copper production. In the

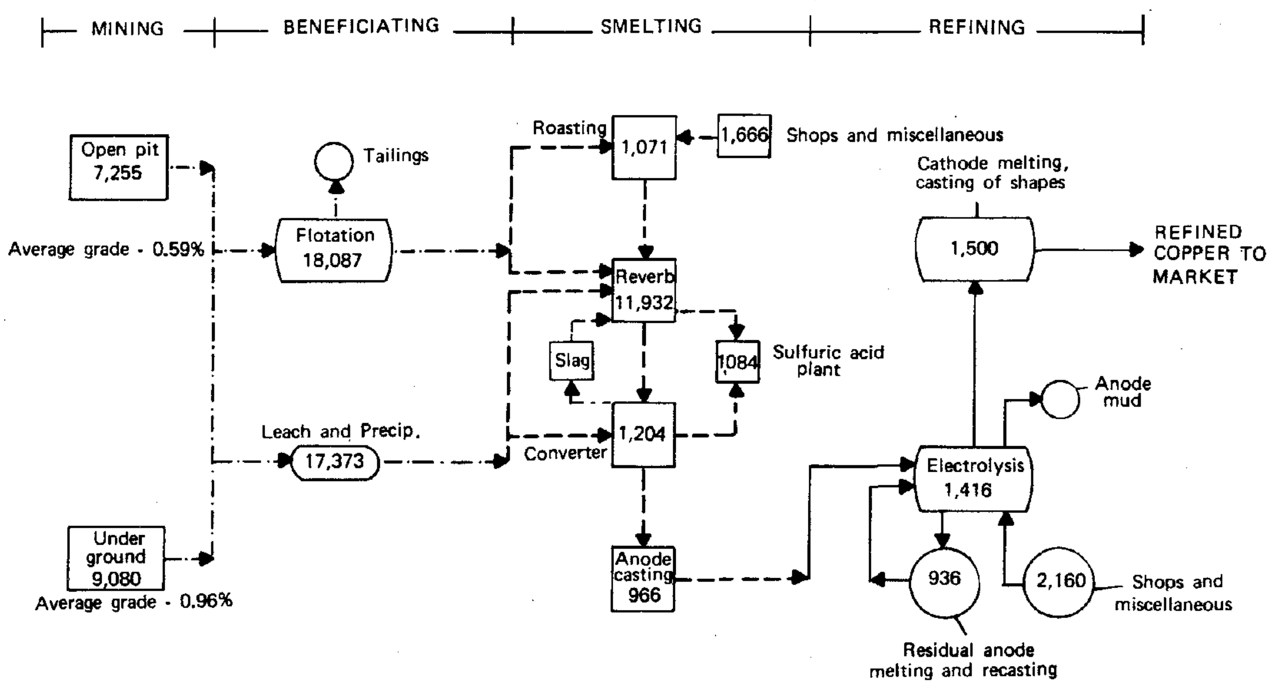

FIGURE 1. - Energy consumed at each stage of copper production—Btu per pound copper.

cases where this occurred, energy consumed in copper production would be overstated.

Energy costs have increased from nearly 2 cents per pound of copper produced in 1963 to over 4.8 cents per pound in 1973 (current dollar value).[3] Energy costs for various stages of production are shown in table 3. Higher energy prices are causing many copper producers to seek means of improving their operations' efficiency. In some cases, producers have been forced to temporarily use other forms of energy when shortages existed.

Recent improvements in production methods will result in changes in the energy mix for some operations. Improvements include Inspiration Consolidated Copper Co.'s new electric reverberatory furnace which is now in operation in Inspiration, Ariz., and the Anaconda Co.'s Arbiter plant in Anaconda, Mont. These processes will use electricity which is already available in both locations.

COPPER MINING AND BENEFICIATION

General

Domestic mine production of copper has been increasing at an average rate of 2.1 percent per year for the past 10 years. During this same period, average yield has decreased from about 15 to 11 pounds of copper per ton of ore. Energy required to mine and beneficiate the lower grade ores has increased nearly 3 percent per year--from 18,973 Btu in 1963 to 25,497 Btu in 1973.

Figure 2, based on analysis of 34 open pit mines, shows the energy consumed at varying quantities of open pit copper production. The operations included on the graph account for nearly all the copper produced by open pit mines. Figure 3, based on data from nine mines, shows the energy consumed in underground copper production. The curves for both figures are based on linear regression analysis. The resulting equation and coefficient of linear correlation (r^2) are shown on each figure. The X in each equation represents millions of pounds of copper mined, while the Y represents billion Btu of energy consumed.

The average grade of copper ore mined by canvassed open pit operations in 1973 was 0.59 percent, while underground mines averaged 0.96 percent. In other words, open pit operations mined an average of 170 pounds of ore for each pound contained copper, while underground operations averaged 104 pounds. Energy requirements for open pit mining averaged 43 Btu per pound of ore, resulting in the consumption of 7,255 Btu per pound of contained copper. Underground mines averaged 87 Btu per pound of ore, or 9,080 Btu per pound of contained copper.

[3]The 1963 cost figure was derived from Bureau of the Census, Census of the Mineral Industry, 1963.

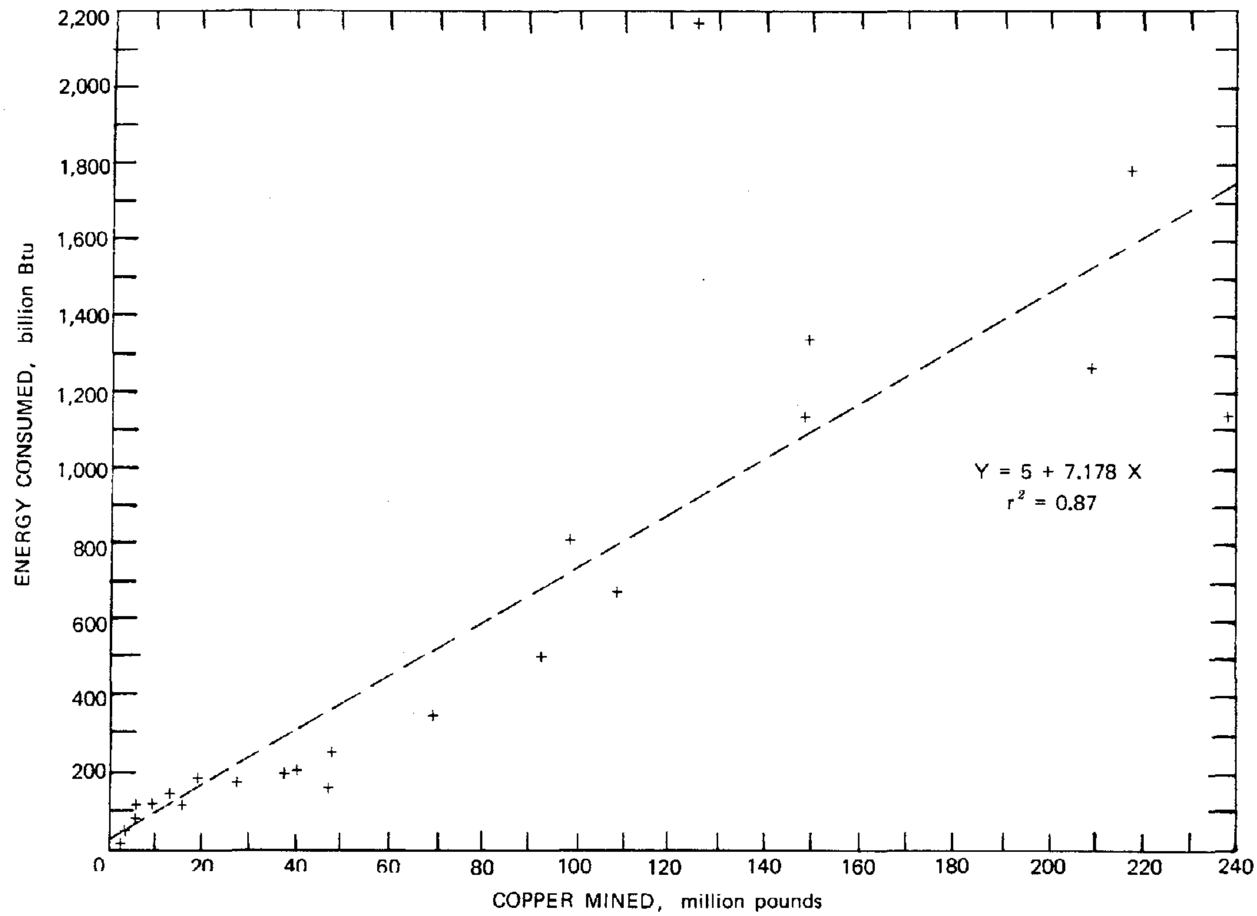

FIGURE 2. - Energy consumed in open pit copper mining.

The operations canvassed accounted for 97 percent of the 3,435,880,000 pounds of copper mined in the United States in 1973. About 78 percent of total copper mined was from open pit operations. Quantities produced by individual mines ranged from less than 100,000 pounds to over 500 million pounds.

Electricity is the major form of energy used in the mining and beneficiation stage. Figure 4 shows how the energy mix for mining and beneficiating has changed from 1963 to 1973. The 1963 data were taken from a Bureau of Census publication and therefore may not be totally comparable with Bureau of Mines data.

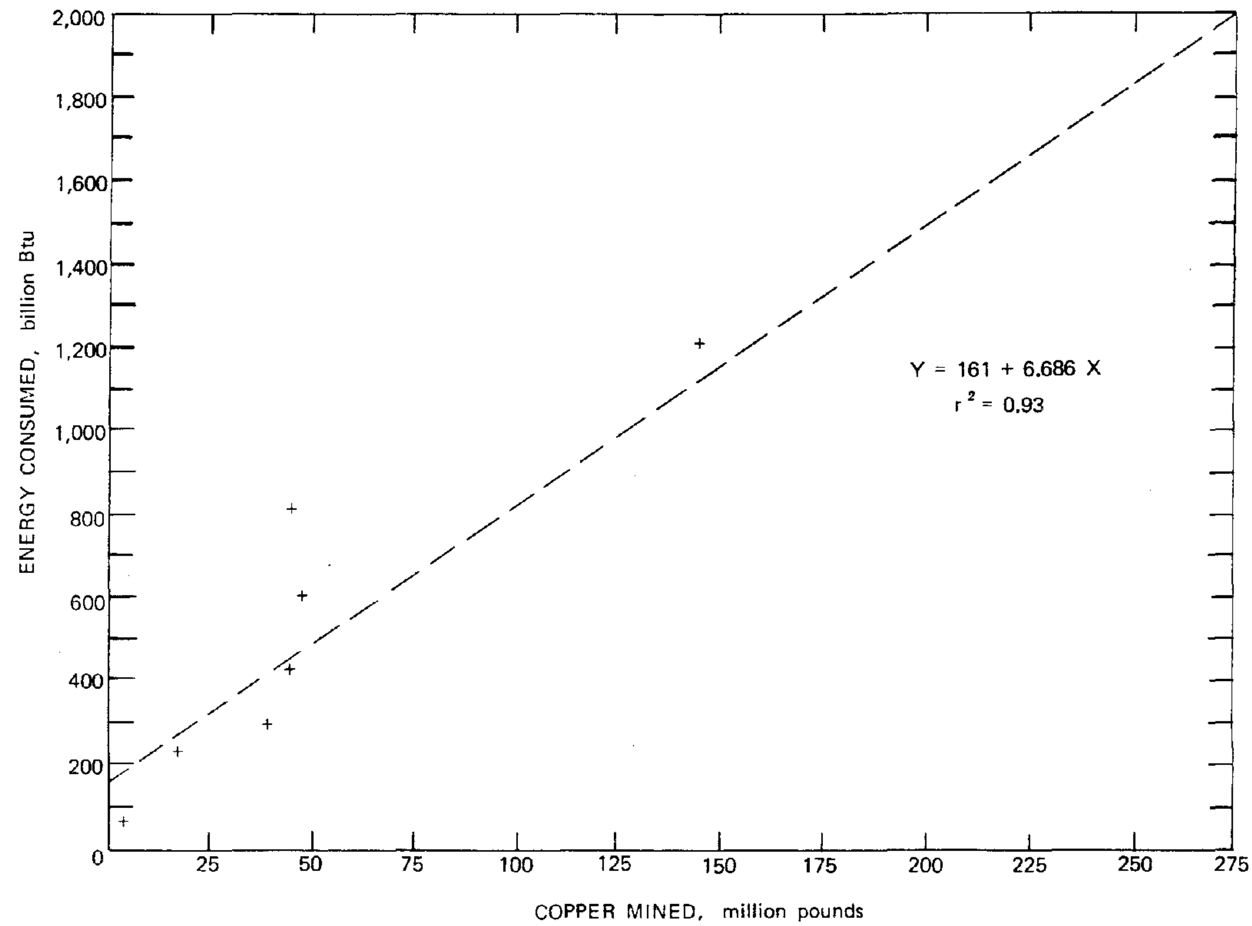

FIGURE 3. - Energy consumed in underground copper mining.

Quantities and cost of energy consumed in copper mining are shown in table 5. Nearly $30 million was spent on energy by copper mines in 1973, resulting in an average cost of 0.858 cent per pound of copper mined.

TABLE 5. - Quantity, Btu equivalent, and cost of energy for copper mining (based on production of 3,435,880,000 pounds of copper)

	Quantity	Btu, billions	Cost, thousand dollars
Electricity.............thousand kW-hr..	1,163,655	11,915	17,024
Heavy fuel.........thousand gallons..	463	69	33
Diesel or light fuel...........do.......	92,212	12,789	11,287
Gasoline.......................do.......	4,320	540	842
Other petroleum................do.......	368	48	44
Natural gas.........million cubic feet..	545	562	230
Coal...............thousand short tons..	2	52	26
Coke...........................do.......	-	-	-
Other energy...........thousand kW-hr..	-	-	-
Total[1]...........................	-	25,975	29,486

[1]Average energy required per pound of copper produced was 7,560 Btu at a cost of $0.0086.

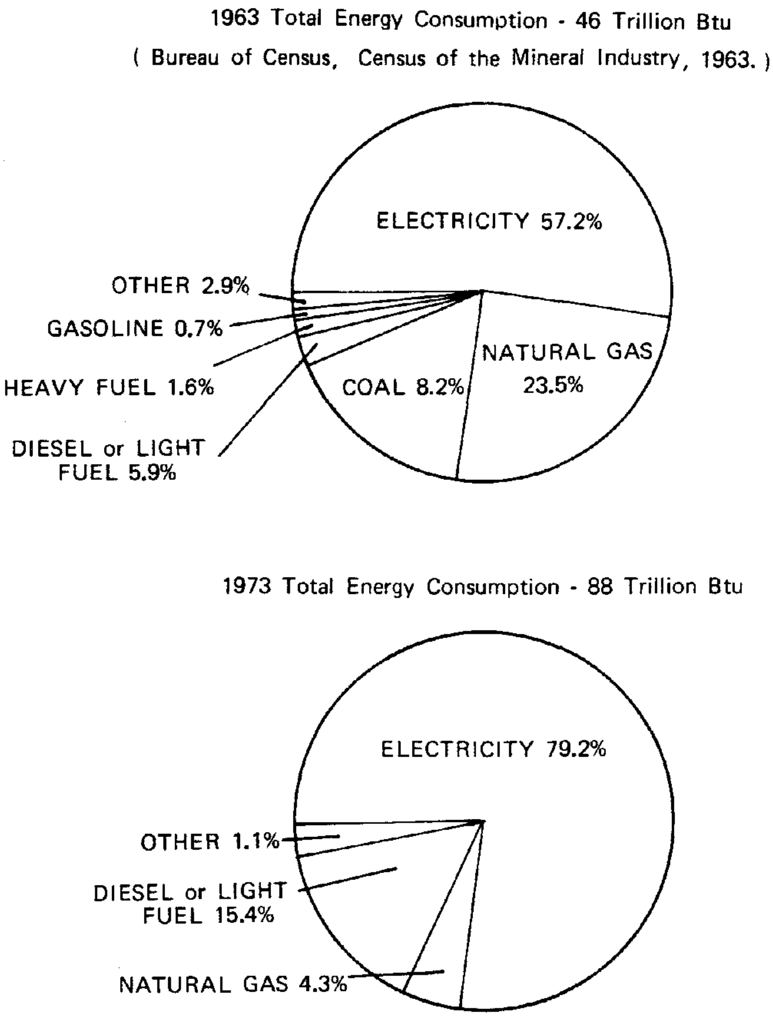

FIGURE 4. - Mining and beneficiating energy mix, 1963 and 1973.

Open Pit Mining

Nearly 2.7 billion pounds of copper was produced from open pit operations in 1973. These operations mined an average of 170 pounds of ore for each pound of contained copper. Open pit mines consumed an average of 7,255 Btu per pound of copper produced, resulting in total energy consumption of 19 trillion Btu.

Figure 5 shows the energy mix for open pit mining in 1973. Diesel oil, used extensively as fuel for drills, shovels, and trucks to mine and move the ore from the pit to the beneficiation plant, was the primary fuel used in open pit operations in 1973. A large portion of oil was also consumed in moving waste rock to dump sites and low-grade ore to leaching locations. Diesel oil and electricity accounted for nearly 96 percent of the energy used in open pit mining.

Cost of the open pit energy mix in 1973 averaged $1.08 per million Btu, resulting in an average energy cost of 0.78 cent per pound of copper mined. An estimated $20 million was spent by open pit operations for energy in 1973.

Underground Mining

In 1973, approximately 756 million pounds of copper, 22 percent of total copper production, was produced from underground operations. Underground mines required an average of 87 Btu per pound of ore mined, resulting in the consumption of 9,080 Btu per pound of copper. Total energy consumption for underground copper mining in 1973 was estimated to be 6.9 trillion Btu.

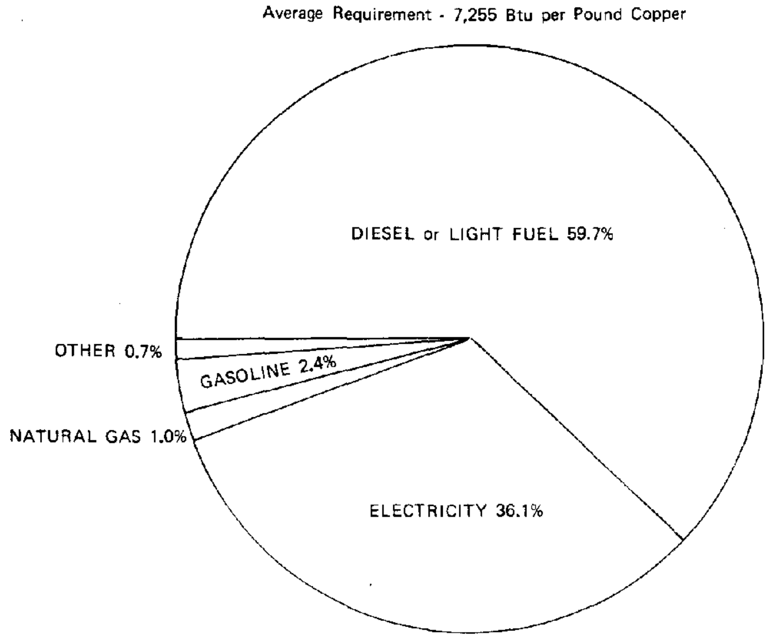

FIGURE 5. - Open pit mining energy mix, 1973.

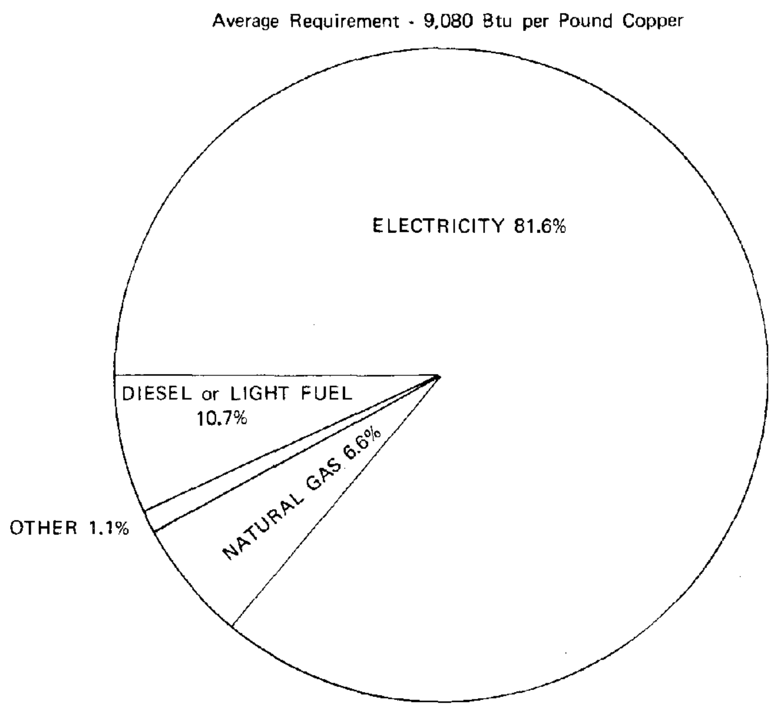

FIGURE 6. - Underground mining energy mix, 1973.

Energy mixes for underground mines differed substantially from those for open pit mines. Figure 6 shows the energy mix for underground mines in 1973. Electricity, used extensively to generate compressed air and in pumping, lighting, and hauling, provided the largest quantity of energy for underground operations.

The cost of the energy consumed in underground mining in 1973 was approximately $1.31 per million Btu, resulting in an energy cost of 1.19 cents per pound of copper mined. Underground mines have a higher cost energy mix than open pit mines because of the larger percentage of electricity they require. In 1973, an estimated $8.9 million was spent for energy used in underground operations.

Copper Ore Beneficiation

Most of the copper mined in open pit and underground operations was concentrated by flotation; however, increasing amounts of low-grade material are being leached and the copper precipitated. In 1973, approximately 94 percent of the domestic ore mined was concentrated by flotation, with the remaining 6 percent being leached and the copper precipitated.

Energy consumed by flotation processes in 1973 averaged 18,087 Btu per pound of copper, while leaching and precipitation averaged an estimated 17,373 Btu. Total energy consumed in copper beneficiation was approximately 62 trillion Btu.

The energy mix used in beneficiating copper ores is shown in table 6. The weighted average of total energy for treating copper ores by flotation and leaching and precipitation was 17,937 Btu per pound of copper.

TABLE 6. - Quantity, Btu equivalent, and cost of energy for copper beneficiation (based on production of 3,435,800,000 pounds of copper)

	Quantity	Btu, billions	Cost, thousand dollars
Electricity.......... thousand kW-hr..	5,608,773	57,428	82,050
Heavy fuel.... ....thousand gallons..	200	30	14
Diesel or light fuel..........do.......	5,300	735	649
Gasoline....................do.......	1,590	199	310
Other petroleum..............do...... ..	181	24	22
Natural gas........million cubic feet..	3,117	3,213	1,317
Coal.............thousand short tons..	-	-	-
Coke........................do.......	-	-	-
Other energy..........thousand kW-hr..	-	-	-
Total[1]...........................		61,629	84,362

[1]Average energy required per pound of copper produced was 17,937 Btu at a cost of $0.0246.

Energy costs for beneficiation are higher per pound of copper produced than for any other stage of copper production. This is because of the extensive use of electricity, which is one of the most expensive forms of energy. In 1973, the energy cost averaged $1.37 per million Btu, which resulted in an average energy cost of 2.46 cents per pound of copper. Nearly $85 million was spent on energy for beneficiating copper in 1973.

COPPER SMELTING AND REFINING

General

Total energy consumed for smelting and refining has risen from an estimated 65 trillion Btu in 1963 to 88 trillion Btu in 1973, an annual increase of 3 percent. Energy increases have been caused by greater production and a rise in the amount of energy required to smelt and refine each ton of copper. Annual copper production has risen from nearly 1.5 million tons in 1963 to nearly 1.8 million tons in 1973. As shown in table 1, in 1963, 21,650 Btu was required to smelt and refine 1 pound of copper. By 1973, this figure had increased nearly 11 percent to 23,935 million Btu. These figures may vary in part because of differences between the 1963 Bureau of Census canvass and the 1973 Bureau of Mines canvass.

Recently enacted Federal and State emission control standards are partly responsible for increased energy consumption by smelters and refineries. Many smelter operators have built sulfuric acid plants to recover sulfur dioxide (SO_2) gases produced during the smelting process. Other types of pollution control equipment have been installed at smelters and refineries, all of which have increased energy consumption.

Several new processes are being utilized in the smelting and refining stages of copper production. Inspiration Consolidation Copper Co. has begun utilizing an electric reverberatory furnace. When this is combined with a redesigned converter, furnace emissions are reduced substantially; SO_2 is recovered and converted to sulfuric acid. Preliminary estimates indicate the process requires about the same or slightly less energy than required in oil or gas reverberatory furnaces. A readily available supply of electric power to Inspiration's operation makes the furnace highly desirable. The process is currently being considered for use at several other locations.

The Anaconda Co. recently completed a 100-ton-per-day Arbiter process plant in Anaconda, Mont. The plant, which cost about half as much as a conventional smelter, should greatly reduce the pollution problem but will probably not significantly reduce energy consumption. According to Metals Week "The Arbiter process does not offer any significant energy savings over the conventional smelter route since the electrowinning step is a comparatively high energy user. The real advantages rest with the low capital cost and the better means of sulfur disposal" (9).[4] The Anaconda Co., which holds patents on the process, is considering licensing it to other copper producers.

Smelting

Smelting consumed more energy than any other stage of copper production in 1973. About 65 trillion Btu was required to smelt the 3,644 million pounds of copper produced in the United States. Energy consumption estimates are based on data from producers accounting for 97 percent of the copper smelted domestically in 1973.

Table 7 indicates the energy mix required in 1973 for smelting. About 76 percent of the energy required was supplied by natural gas. Most operations use natural gas to fire their reverberatory furnaces, although several operations were forced to convert to heavy fuel oil for brief periods when shortages of natural gas occurred.

Energy required for the smelting stage of copper production in 1973 averaged 17,923 Btu per pound of copper produced. This includes 1,666 Btu consumed by supporting shops, plants, and other miscellaneous uses.

[4] Underlined numbers in parentheses refer to items in the list of references preceding the appendixes.

TABLE 7. - Quantity, Btu equivalent, and cost of energy for copper smelting (based on production of 3,643,556,000 pounds of copper)

	Quantity	Btu, billions	Cost, thousand dollars
Electricity.............thousand kW-hr..	223,545	2,289	3,218
Heavy fuel...........thousand gallons..	47,316	7,083	3,393
Diesel or light fuel..........do.......	4,180	580	512
Gasoline.....................do.......	354	44	69
Other petroleum...............do.......	81	11	10
Natural gas.........million cubic feet..	48,228	49,722	20,673
Coal..............thousand short tons..	182	4,383	2,145
Coke.........................do.......	42	1,104	1,552
Other energy...........thousand kW-hr..	8,796	90	140
Total[1]...........................		65,305	31,712

[1]Average energy required per pound of copper produced was 17,923 Btu at a cost of $0.0087.

Energy costs for smelting copper are shown in table 7. In 1973, these costs averaged 49 cents per million Btu, which resulted in an average cost of 0.87 cent per pound of copper smelted. The large percentage of natural gas consumed, one of the lowest-cost forms of energy in 1973, helped lower the average cost of smelting. An estimated $31.7 million was spent on energy for smelting in 1973.

Figure 1 shows energy consumed at various stages. Copper concentrates, mixed with flux, are heated in roasting ovens. Roasting requires an average of 1,071 Btu per pound of copper.

In many copper smelters, the concentrates move directly to the reverberatory furnaces, bypassing the roasting stage. The concentrates are melted, and a large portion of the impurities is removed in the form of a slag. Reverberatory furnaces consume the largest amount of energy in the smelting and refining process--11,932 Btu per pound of copper. An estimated 1,084 Btu is required for the removal of SO_2 from the stack gases and the production of sulfuric acid.

Copper from the reverberatory furnaces, in the form of copper matte, is then transferred to the converter. Air is injected into the molten matte to oxidize the iron and other impurities, and silica is added to collect the oxides. The resulting slag is poured off and returned to the reverberatory furnaces. Although no energy is required to heat the charge in the converters, about 1,204 Btu is required per pound of copper converted to keep the converters hot between charges and in other operations, such as air injection.

The blister copper produced in the converters then moves to a refining furnace where it is purified to plus 99.5 percent copper and cast into anodes. The casting stage requires about 966 Btu per pound of copper produced.

Copper that has been leached and precipitated from low-grade oxide ores may enter the smelting process at the reverberatory, converter, or casting stage; or it may be shipped directly to an electrolytic refinery for casting into anodes. The later the leached and precipitated copper (cement copper) enters the smelting or refining process, the less energy is consumed. Therefore, from an energy conservation standpoint, it is most desirable to have the cement copper enter at the refinery stage. However, the purity of the cement copper, the quantity of other metals alloyed with it, the size of the leaching and precipitating operation, and the capability of the smelter and refinery dictate at which stage the copper will enter. Currently, nearly all leached and precipitated copper enters the smelting process at the reverberatory or converter stage.

Refining

In 1973, U.S. refineries produced 3,737 million pounds of copper from domestic and foreign ores. Energy requirements for refining in 1973 averaged 6,012 Btu per pound of copper produced, resulting in a total of about 22 trillion Btu consumed. Energy estimates are based on data from refineries accounting for 25 percent of domestic refinery production.

Most copper produced in the United States is electrolytically refined, which requires three principal operations: (1) Electrolysis of the copper, (2) remelting and recasting of the residual anodes from the electrolysis stage, and (3) cathode melting and casting into basic shapes for shipment to consumers.

The electrolysis stage requires an average of 1,416 Btu per pound of copper. Melting and casting of the residual anodes requires approximately 936 Btu per pound. The final stage of refining, melting the cathodes and casting into shapes, requires about 1,500 Btu per pound of copper. The cathodes are melted and cast into wirebars and copper billets of assorted sizes and shapes for shipment to copper consumers.

As shown in table 8, electricity was the major form of energy consumed in refining copper. Most of the electricity is consumed directly in electrolysis. Natural gas is used in the residual anode melting and casting stage and in the final cathode melting and casting stage.

Energy costs for refining copper in 1973, also shown in table 8, averaged approximatley $1.06 per million Btu, or 0.64 cent per pound of refined copper. Electricity accounted for 62 percent of energy consumption and 82 percent of energy cost to copper refineries in 1973.

TABLE 8. - Quantity, Btu equivalent, and cost of energy for copper refining (based on production of 3,736,976,000 pounds of copper)

	Quantity	Btu, billions	Cost, thousand dollars
Electricity............thousand kW-hr..	1,369,659	14,024	19,653
Heavy fuel...........thousand gallons..	6,739	1,009	483
Diesel or light fuel..........do.......	6,934	962	849
Gasoline.......................do.......	459	57	90
Other petroleum...............do.......	72	9	9
Natural gas........million cubic feet..	6,124	6,314	2,674
Coal..............thousand short tons..	-	-	-
Coke... ....do.......	4	93	130
Other energy..........thousand kW-hr..	-	-	-
Total[1]...........................		22,468	23,888

[1]Average energy required per pound of copper produced was 6,012 Btu at a cost of $0.0064.

FUTURE ENERGY DEMAND BY THE COPPER INDUSTRY

A recent Bureau of Mines forecast predicts domestic demand for copper in the year 2000 to be 2.5 times current consumption.[5] Based on an annual increase of 3.5 percent, demand is expected to range between 4.1 and 7.5 million tons, with a probable demand of 6.0 million tons by the year 2000. An estimated 4.2 million tons of this demand will be supplied from primary copper. The remaining 1.8-million-ton requirement will be supplied by secondary copper.

Copper consumption in the year 2000 is expected to be as follows: Electrical, 4.3 million tons; construction, 0.6 million tons; machinery, 0.4 million tons; transportation, 0.25 million tons; ordnance, 0.15 million tons; and other (including jewelry, pigments, and coinage), 0.3 million tons.[5]

The United States is expected to supply 90 percent of the estimated 4.2 million tons of primary copper required to meet domestic needs in the year 2000. This leaves approximately 2.2 million tons to be supplied by secondary recovery and imports. An alternative to imports would be to utilize the additional 2 million tons of scrap that will be potentially available in the year 2000 but may not be recovered (5). Increased recovery of copper from secondary sources would help alleviate the dependence of the United States on foreign sources and, as discussed in the following paragraphs, reduce energy consumption in the copper industry.

Because copper recovered from secondary sources requires from three to seven times less energy than primary production, a significant potential exists for the recovery of scrap copper. If scrap were used in lieu of

[5] Preliminary tables from Bureau of Mines Bulletin 667, the 1975 edition of Mineral Facts and Problems.

imports required to meet domestic demand in the year 2000, an estimated 100 to 125 trillion Btu could be conserved by the producing nation.

The United States could, therefore, meet total domestic copper needs by recovering additional scrap which under normal circumstances would be lost. As the price of energy and demand for copper increase and the grade of copper ores decreases, domestic copper producers will undoubtedly recover increasing quantities of copper scrap.

If domestic copper demand reaches 6.0 million tons by the year 2000, an estimated 375 trillion Btu will be required to produce the domestic primary copper supply of 3.8 million tons. This estimate is low because the assumption is made that energy requirements for each ton of copper produced will remain constant in future years. Increased energy requirements caused by mining lower grade ores and meeting Federal and State pollution control standards will probably exceed any decreased requirements made possible by technological improvements. For example, if the average grade of domestic ore were to drop to 0.2 percent copper by the year 2000, nearly 60 million Btu would be required to mine each ton of copper, raising the total energy consumption for copper production by an estimated 135 trillion Btu.

SUMMARY AND CONCLUSIONS

The projected 150-percent increase in domestic copper consumption by the turn of the century will increase copper producers' energy needs significantly. The mining of lower grade copper ores and strict Federal and State pollution control standards will continue to contribute to the increase. Accompanying the energy consumption increase will be higher energy prices and, at times, shortages of various energy fuels which will temporarily force copper producers to switch to a more readily available energy mix. It is expected that higher energy costs will lead to continued research to find new processes or improve present processes to reduce energy consumption.

Copper recovered from scrap may play an important role in domestic supply in future years since it requires three to seven times less energy than the production of primary copper. As a result of recent energy price increases, large quantities of copper scrap which are currently disposed of may be economically recovered in the near future. An increase in scrap recovery would both decrease domestic energy consumption and play an important role in lowering import requirements.

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APPENDIX A.--Estimated 1973 energy costs to copper producers[1]

Area	Electricity,[2] cents/kW-hr	Heavy fuel,[3] cents/gal	Diesel or light fuel,[4] cents/gal	Gas,[5] cents/gal	Other petroleum,[6] cents/gal	Natural gas,[7] cents/1,000 cu ft	Coal,[8] dol/ton	Coke,[9] dol/ton	Other energy,[2] cents/kW-hr
East North-Central (Michigan)........	1.624	7.17	12.24	19.5	12.0	66.577	11.77	-	1.624
East South-Central (Tennessee).......	1.053	7.17	12.24	19.5	12.0	48.580	-	-	1.053
West South-Central (Oklahoma and Texas)............	1.297	7.17	12.24	19.5	12.0	33.978	-	-	1.297
Mountain (Montana, Idaho, New Mexico, Arizona, Utah, Nevada)...........	1.458	7.17	12.24	19.5	12.0	42.245	11.77	36.55	1.458
Pacific (Washington)......	1.305	7.17	12.24	19.5	12.0	54.783	-	-	1.305

[1]Since actual energy costs are dependent on the duration of the contract, quantity purchased, locality, and transportation charges, energy costs vary from operation to operation.
[2]Edison Electric Institute, Yearbook of the Electric Utilities, tables 22S and 36S.
[3]Oil and Gas Journal, average midcontinent price, No. 6 (max. 1 percent S), various months.
[4]Oil and Gas Journal, average midcontinent price, diesel oil 58 di and above, various months.
[5]Platts Oil Price Handbook.
[6]Estimated.
[7]Bureau of Mines Yearbook 1973, Natural Gas chapter, table 13.
[8]Bureau of Mines Yearbook 1973, Coal chapter, table 1.
[9]Bureau of Mines Yearbook 1973, Coke chapter, table 18.

APPENDIX B.--BUREAU OF MINES ENERGY CANVASS FORM

OFFICE OF THE DIRECTOR

United States Department of the Interior

BUREAU OF MINES
WASHINGTON, D.C. 20240

In Reply Refer To:
EBM-MRED-MS-FM

Gentlemen:

The energy situation requires that the Government have accurate and detailed information on the use of energy by the minerals industry in order to facilitate planning for current and future needs.

The Bureau of Mines under its legislative authorities has broad responsibility for the collection and analysis of information essential to the formulation of mineral resource policy under the Mining and Minerals Policy Act of 1970 and other legislation. Recommendations to alleviate energy shortages in the mineral industry will depend on the availability of accurate and complete information. Energy data published by the Bureau of the Census deal with State, regional, and national aggregates; this survey will supplement and update the Census information and provide data necessary for projecting energy requirements based on mineral demand forecasts.

Your cooperation is requested in completing and returning promptly the enclosed mine, mill, and smelter energy utilization report form.

Sincerely yours,

JDMorgan
Asst. Director

Enclosure

Form 6-1017-IX
(September 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON, D.C. 20240

MINE, MILL, AND SMELTER ENERGY

INFORMATION SUPPLEMENT— 1973

O.M.B. No. 42-S73014.
Approval expires December 1974.

INDIVIDUAL COMPANY
DATA-CONFIDENTIAL

(Please correct if name or address has changed. Enter in the space below the name of mine or plant and location.)

Name of mine or plant __________ State __________
County __________ Section __________ Township __________ Range __________
Give name and address of operator if operated by someone else during year __________

Energy Consumed by Source and Use Pattern During the Year ***(See instructions on reverse side.)***

Source (1)	Code	Unit of measure (2)	Quantity (3)	Use pattern *(in percent)* Mining (4)	Beneficiating (5)	Smelting (6)	Other (7)
Electricity *(purchased)*	01	Thousand kilowatt hours					
Fuel							
Petroleum							
Heavy fuel oils	02	Thousand gallons					
Diesel or light fuel oils	03	Thousand gallons					
Gasoline	04	Thousand gallons					
Other *(specify)* ____	05	Thousand gallons					
Natural gas	06	Million cubic feet					
Coal*	07	Thousand short tons					
Coke *(purchased)*	08	Thousand short tons					
Other energy *(specify)* ____	09	*(Specify unit)*					

Type of coal consumed** ***(Please check) ☐ (10) Bituminous ☐ (11) Anthracite ☐ (12) Lignite

Code	*For Bureau of Mines office use*
99	

Name of person to be contacted regarding this report	Tel. area code	No.	Ext.

Address No. Street	City	State	Zip

May tabulations be published which could indirectly reveal the data reported above? ☐ (1) Yes ☐ (2) No

Signature	Title	Date

Form 6–1017–IX
(September 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON, D.C. 20240

O.M.B. No. 42-S73014.
Approval expires December 1974.

INDIVIDUAL COMPANY
DATA–CONFIDENTIAL

Unless authorization is granted in the section above the signature, information furnished in this report will not be disclosed outside the Department of the Interior, except as provided by law.

MINE, MILL, AND SMELTER ENERGY

INFORMATION SUPPLEMENT— 1973

Please separate forms at perforations

An extra copy is provided for your files

(Please correct if name or address has changed. Enter in the space below the name of mine or plant and location.)

Name of mine or plant ______ State ______
County ______ Section ______ Township ______ Range ______
Give name and address of operator if operated by someone else during year ______

Energy Consumed by Source and Use Pattern During the Year ***(See instructions on reverse side.)***

Source (1)	Code	Unit of measure (2)	Quantity (3)	Use pattern *(in percent)* Mining (4)	Bene-ficiating (5)	Smelting (6)	Other (7)
Electricity *(purchased)*	01	Thousand kilowatt hours					
Fuel							
Petroleum							
Heavy fuel oils	02	Thousand gallons					
Diesel or light fuel oils	03	Thousand gallons					
Gasoline	04	Thousand gallons					
Other *(specify)* ______	05	Thousand gallons					
Natural gas	06	Million cubic feet					
Coal*	07	Thousand short tons					
Coke *(purchased)*	08	Thousand short tons					
Other energy *(specify)* ______	09	*(Specify unit)*					

Type of coal consumed** ***(Please check) ☐ (10) Bituminous ☐ (11) Anthracite ☐ (12) Lignite

Code	For Bureau of Mines office use
99	

Name of person to be contacted regarding this report	Tel. area code	No.	Ext.

Address No. Street	City	State	Zip

May tabulations be published which could indirectly reveal the data reported above? ☐ (1) Yes ☐ (2) No

Signature	Title	Date

GENERAL INSTRUCTIONS

This canvass covers mines, quarries, pits, mills, coal preparation plants, plants using chemical and solution extraction methods, and smelters. By definition, smelters include base metal smelters, aluminum reduction works, ferroalloy plants, and iron blast furnace plants.

Please complete this form and return one copy to the Bureau of Mines, in the enclosed envelope. Complete a separate form for each establishment. In completing this form, reasonable estimates may be used wherever exact figures are not available.

The results of this survey are used in statistical publications of the Bureau of Mines. These publications have a variety of users, including industry, State and Federal Government, private research agencies, and consulting firms. The publications often provide guidance on policy or assist users in decision-making. They form the statistical basis for action. Your cooperation is needed to make the results of this survey comprehensive, meaningful, accurate, and timely.

If you have any questions concerning this form, please contact the Division of Ferrous Metals, Bureau of Mines, Department of the Interior, Washington, D.C. 20240. Telephone 703-557-1568.

SPECIFIC INSTRUCTIONS

(Please follow these guides when completing the report form)

Energy Consumed by Source and Use Pattern During the Year.

Enter appropriate figures for energy consumed by source and use.

Report all fuels used in mining, beneficiation, and smelting for such purposes as power generation, heating, and equipment operation.

Those establishments that generate power with their own hydro-electric facilities should use the "Other energy *(specify)*" line, Code 09.

Use-pattern columns (4), (5), (6), and (7) should total 100 percent for each source entry.

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