Updating the *CE* Plant Cost Index

Changing ways of building plants are reflected as this widely used index is brought into the 21st century

TABLE 1. STRUCTURE OF THE CECPI

A. Equipment Index, includes the following sub-indexes:
• Heat exchangers and tanks • Process machinery • Pipe, valves & fittings • Process instruments • Pumps & compressors • Electrical equipment • Structural supports & miscellaneous
B. Construction Labor Index
C. Buildings Index
D. Engineering and Supervision Index
CE Plant Cost Index (composite)

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The *Chemical Engineering* Plant Cost Index (CEPCI) is an established institution. Since its introduction in 1963 [*1*], it has been published in each and every issue of *CE*. For more than 37 years, chemical-process-industry (CPI) professionals — engineers, managers, and technicians — have used the CEPCI to adjust process plant construction costs from one period to another. This index — rather, indexes, as it consists of a composite index and eleven sub-indexes — has received such wide acceptance that it has even been written into construction-contract cost-escalation clauses.

The CEPCI has a history of revisions. Most of these have been cosmetic, such as renaming the "Fabricated equipment" sub-index to the more descriptive "Heat exchangers and tanks" sub-index. The most recent, and most significant, revision — more like an overhaul — occurred in 1982 [*2*]. The major changes included reducing the number of components from 110 to 66, replacing many components with more suitable ones, and revising the productivity factor downward from 2.50% to 1.75%. (See next page for an explanation of the productivity factor.) The 1982 changes deliberately retained the structure of the CEPCI.

The set of sub-indexes has remained unchanged for nearly four decades — decades that have seen major changes in the CPI, especially in plant design and operation. We have not changed the data series and the relative weights since 1982. That is a long time to freeze an index, and does not necessarily reflect recent changes. For that reason, we have decided it was time for the CEPCI to be revised again, this time to bring it into the twenty-first century. The structure is not being changed, but many underlying details are being updated.

The established structure

Before describing the latest CEPCI revision, we need to review its structure and some history. Table 1 shows that the composite index is built from seven component-indexes and four sub-indexes, For all of these, values have been reported running back to 1947. Table 2 lists annual values of the four sub-indexes and the composite index for the years 1963 to 2000. Component-index data and an extension back to 1947 can be purchased from *CE's* editorial department. Each annual index is the arithmetic mean of the monthly indexes.

Details of computing the values will be discussed below. For now, we will stick with an outline, as shown in Table 1. The component-indexes are compiled, and with appropriate weighting factors, are added up to make up the Equipment Index. Independently, three other sub-indexes are compiled, and with appropriate weighting and normalizing, the four sub-indexes add up to the CEPCI.

While Table 2 is informative, it is a lot easier to see trends and relative changes among the indexes when plotted in Figure 1. A cursory look at this figure tells us that none of the five indexes increased monotonically during these 37 years. They had their "ups and downs," but all of them were significantly higher in 2000 than in 1963. The Equipment sub-index exhibited the most growth (approximately 340%) over this period, followed by the composite CEPCI, and the Buildings, Engineering and Supervision, and Construction Labor sub-indexes, respectively. The relatively steep rise in the Equipment sub-index was partly due to sharp increases in fabricated equipment prices, which were driven, in turn, by jumps in the costs of raw materials (for instance, stainless steel). Because this sub-index contributed so much (61%) to the composite CEPCI, the latter exhibited very similar behavior; the two curves are nearly parallel.

There is another reason for the relatively modest increases in the other sub-indexes — the CEPCI productivity factor. This factor, which discounts changes in the labor-cost components in the sub-indexes, tends to dampen increases in these sub-indexes. An index with large labor components, such as Construction Labor, is more influenced by the productivity factor than those with less-significant labor cost elements (such as Equipment).

The five index curves change slopes downward around the year 1982. This was the year of the last major CEPCI revision. This revision involved a change in the productivity factor, as well as major reductions in the number of index components. Taken to-

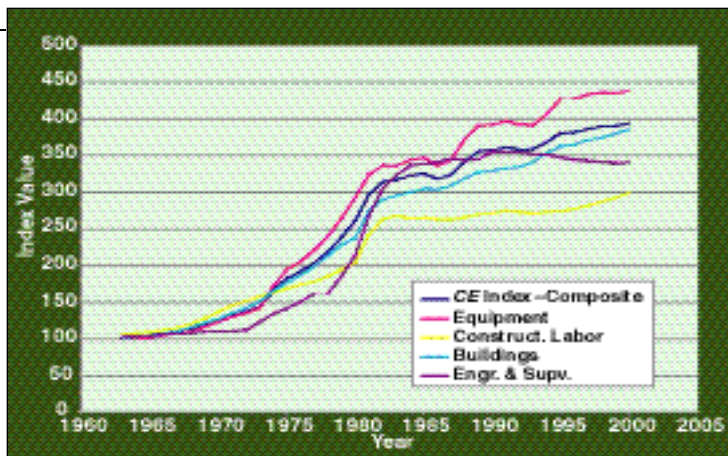| Year	Composite CE Index	Equipment	Construction labor	Buildings	Engineering and super-vision
1963	102.4	100.5	107.2	102.1	103.4
1964	103.3	101.2	108.5	103.3	104.2
1965	104.2	102.1	109.7	104.5	104.8
1966	107.2	105.3	112.4	107.9	106.8
1967	109.7	107.7	115.8	110.3	108.0
1968	113.7	109.9	121.0	115.7	108.6
1969	119.0	116.6	128.3	122.5	109.9
1970	125.7	123.8	137.3	127.2	110.6
1971	132.3	130.4	146.2	135.5	111.4
1972	137.2	135.4	152.2	142.0	111.9
1973	144.1	141.8	157.9	150.9	122.8
1974	165.4	171.2	163.3	165.8	134.4
1975	182.4	194.7	168.6	177.0	141.8
1976	192.1	205.8	174.2	187.3	150.8
1977	204.1	220.9	178.2	199.1	162.1
1978	218.8	240.3	185.9	213.7	161.9
1979	238.7	264.7	194.9	228.4	185.9
1980	261.2	292.6	204.3	238.3	214.0
1981	297.0	323.9	242.4	274.9	268.5
1982	314.0	336.2	263.9	290.1	304.9
1983	317.0	336.0	267.6	295.6	323.3
1984	322.7	344.0	264.5	300.3	336.3
1985	325.3	347.2	265.3	304.4	338.9
1986	318.4	336.3	263.0	303.9	341.2
1987	323.8	343.9	262.6	309.1	346.0
1988	342.5	372.7	265.6	319.2	343.3
1989	355.4	391.0	270.4	327.6	344.8
1990	357.6	392.2	271.4	329.5	355.9
1991	361.3	396.9	274.8	332.9	354.5
1992	358.2	392.2	273.0	334.6	354.1
1993	359.2	391.3	270.9	341.6	352.3
1994	368.1	406.9	272.9	353.8	351.1
1995	381.1	427.3	274.3	362.4	347.6
1996	381.7	427.4	277.5	365.1	344.2
1997	386.5	433.2	281.9	371.4	342.5
1998	389.5	436.0	287.4	374.2	341.2
1999	390.6	435.5	292.5	380.2	339.9
2000	394.1	438.0	299.2	385.6	340.6

Indexes' base: 1957-59 = 100.0

FIGURE 1. The major indexes show an irregular rise over 37 years

of personal computers and other electronic tools, and less-evident (to non-construction professionals, at least) innovations as the implementation of modular construction techniques. However, Matley said that the factor, "should not be considered to account for changes in productivity arising from improvements in the quality of construction work-management… [nor should it] be regarded as reflecting productivity changes due to advances in the skill, experience or motivation of the workforce. Lastly, the factor does not take into account regional variations in construction wages" [3].

Let us do the math and enter the productivity factor into the calculation of the CEPCI composite and its sub-indexes. It is used on every labor-cost component within a sub-index, component index, or the composite index. Take the raw change in a labor-cost component and multiply it by the productivity factor to obtain the adjusted change in that component. This adjusted change is then an input to the calculation of the appropriate CEPCI sub-index, and the composite index.

The productivity factor is calculated via Equation (1):

$$P.F. = 1/(1 + p/12)^n \qquad (1)$$

where: $P.F. = productivity\ factor\ (< 1)$
p = Annual growth in construction labor productivity (fraction)
n = Number of months between January 1947 and the index-update month

The index is calculated monthly. That is why the average productivity increase appears as $p/12$.

For instance, suppose that the raw (unadjusted) increase in the Engineering cost component from February 1963 to August 2000 was 400% (or 4.00). Here is how to calculate the adjusted change in this component: Substitute an annual productivity growth rate of 2.2% or 0.022 (this value is verified p.69) and the number of months from January 1947 to August 2000 (53 $\times$ 12 + 8 = 644). Equation (2) solves for a productivity factor of:

$$P.F. = 1/(1 + 0.022/12)^{644} = 0.3074 \qquad (2)$$

The adjusted increase in the engineering cost component is 0.3074 $\times$ 400% = 123%.

The exponent n in Equation (1) is calculated from January 1947 instead of from February 1963, the month and year the CEPCI was introduced, because 1947 is the year that the Marshall and Swift (M&S; formerly Marshall and Stevens) Equipment Cost Index was started as a regular feature of *CE* [4]. We suspect that Arnold and Chilton derived the productivity factor from this data, but they did not leave a paper trail.

Despite the fact that the M&S index is based on used-equipment prices, while the CEPCI is built around new plant-construction costs, trends in the M&S have been comparable to the CEPCI. The quarterly M&S index is published on *CE*'s Economic Indicators page, along with the VAPCCI (see box, p. 69) and other indexes.

Two questions of engineering philosophy intrude here and need addressing. Why do we use a productiv-

gether, these changes significantly affected the next 18 years of the CEPCI and its sub-indexes. There were other macroeconomic trends that also influence the data; such as a decline in interest rates over 20 years from 20 to 2%. The inflationary 1970s have come and gone but left their mark.

Meet the productivity factor
We have mentioned the CEPCI productivity factor several times already without explaining what it is or how it is calculated. In 1982 Matley [3] explained that the productivity factor "should be thought of as a technological productivity factor [that is] predicated on advances in working tools and techniques." These advances include such obvious ones as the proliferation

ity factor at all? Why not just leave the labor-cost components unadjusted?

According to Arnold and Chilton [5], "All cost indexes that have labor rates as components and that do not make corrections for labor productivity have built into them what index technicians call an upward bias." They felt that, without labor productivity corrections, indexes will, over time, overstate true (as opposed to apparent) labor-cost changes. However, we should note that the productivity factor dampens labor-cost decreases, as well as increases. As mentioned earlier, Figure 1 displays the effect of labor productivity on index trends.

Assembling the CEPCI data

The productivity factor is one of 54 inputs that are used for calculating the updated CEPCI and sub-indexes. We will discuss accessing the other key inputs used in their calculations and how this calculation is performed.

We said that each index and subindex is the weighted sum of several components. Most of these components correspond to Producer Price Indexes (PPIs), updated and published monthly by the U.S. Department of Labor's Bureau of Labor Statistics (BLS; Washington, D.C.). According to the BLS definition, the PPIs, "track the average-change in net transaction prices that domestic producers in the mining, manufacturing, agriculture, and forestry sectors, as well as selected services industries, receive for the products that they make and sell." The price quotations that the BLS uses to build these indexes come from a statistically chosen sample of representative transactions obtained from a statistically chosen sample of representative producers in each 600 or so industries. "In all, the PPI includes roughly 100,000 price quotations from about 25,000 domestically producing establishments, resulting in the publication of approximately 13,000 indexes" [6].

From these several thousand indexes, 41 PPIs have been selected as inputs to the CEPCI and sub-indexes. These PPIs cover products as diverse as carbon steel plates, fans and blowers, concrete pipe, and lighting fixtures. All of these items and many more are key elements in a typical

TABLE 3. REVISED CEPCI COMPONENTS AND WEIGHT FACTORS				
Component	BLS index number	Component weight factor	Component group—Level I (weight factor)	Component group—Level II (weight factor)
Plates, carbon steel	pcu3312#412	0.140	HEAT EXCHANGERS AND TANKS (0.338)	EQUIPMENT (0.50675)
Plates, stainless steel	pcu3312#45	0.110		
Pressure tubing, welded, carbon steel	wpu10170628	0.043		
Pressure tubing, seamless, carbon steel	wpu10170628	0.043		
Nonferrous mill shapes	wpu1025	0.043		
Plates, alloy	pcu3312#431	0.110		
Hot rolled bars, plates, and structural shapes	pcu3312#4	0.110		
Storage tanks, 6,000 gal or less	wpu10720104	0.027		
Storage tanks, over 6,000 gal	wpu10720104	0.025		
Metal tanks	wpu10720152	0.021		
Custom tanks, 3/4 in. and less	wpu10720136	0.082		
Other custom tanks, field assembled	wpu10720152	0.010		
Petroleum storage tanks	wpu10720104	0.010		
Subtotal, heat exchangers and tanks – components	——	0.774		
Subtotal, heat exchangers and tanks – labor	eeu31340006	0.226		
Total for Heat Exchangers and Tanks	——	**1.000**		
Plates, carbon steel	pcu3312#412	0.105	PROCESS MACHINERY (0.128)	
Sheets, hot-rolled, carbon steel	pcu3312#311	0.030		
Cold-rolled sheets and strip	pcu3312#7	0.010		
Foundry and forge shop products	wpu1015	0.060		
Industrial material-handling equipment	wpu1144	0.075		
Fans and blowers, except portable	wpu1147	0.025		
Chem. ind. machinery	wpu116604	0.250		
Integral-hp motors and generators	pcu3621#2	0.035		
Crushers, pulverizers and screening machines	wpu119202	0.150		
Concrete ingredients	wpu132	0.030		
Subtotal, Process machinery – components	——	0.770		
Subtotal, Process machinery – labor	eeu31350006	0.230		
Total for Process Machinery	——	**1.000**		
Plastic construction products	wpu0721	0.050	PIPES, VALVES, AND FITTINGS (0.190)	
Line and standard pipe, carbon steel	wpu10170618	0.400		
Mechanical tubing, carbon steel	wpu10170629	0.100		
Copper and brass mill shapes	wpu102502	0.100		
Concrete pipe	wpu1332	0.050		
Metal valves, except fluid power	wpu114902	0.200		
Metal pipe fittings, flanges, and unions	wpu114903	0.100		
Total for pipes, valves and fittings	——	**1.000**		

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TABLE 3. REVISED CEPCI COMPONENTS AND WEIGHT FACTORS (Continued)

Component	BLS index number	Component weight factor	Component group—Level I (weight factor)	Component group—Level II (weight factor)
Sheets, hot-rolled, carbon steel	pcu 3312#311	0.057	PROCESS INSTRUMENTS (0.105)	EQUIPMENT (0.50675)
Sheets, cold-rolled, carbon steel	wpu10170711	0.014		
Foundry and forge shop products	wpu1015	0.077		
Nonferrous mill shapes	wpu11025	0.060		
Copper and brass mill shapes	wpu1102502	0.053		
Integral-hp motors and generators	pcu3621#2	0.036		
Electronic components and accessories	wpu11178	0.400		
Metal valves, except fluid power	wpu114902	0.053		
Subtotal, Instrument and controls – components	——	0.750		
Relays & industrial controls – labor	eeu31362506	0.063		
Process control instruments – labor	eeu31382306	0.187		
Subtotal, Instrument and controls mfg. – labor	——	0.250		
Total for process instruments	——	**1.000**		
Industrial pumps	wpu114102	0.900	PUMPS AND COMPRESSORS (0.064)	
Air compressors, stationary	wpu114103	0.050		
Gas compressors, stationery	wpu114104	0.025		
Other compressors and vacuum pumps	wpu114111	0.025		
Total for pumps and compressors	——	**1.000**		
Nonferrous wire and cable	wpu1026	0.057	ELECTRICAL EQUIPMENT (0.070)	
Lighting fixtures	wpu1083	0.188		
Integral-hp motors and generators	pcu 3621#2	0.306		
Motors, generators, generator sets	wpu1173	0.043		
Transformers and power regulators	wpu1174	0.146		
Switchgear, switchboard equipment	wpu1175	0.260		
Total for electrical equipment	——	**1.000**		
Prepared paint	wpu0621	0.024	STRUCTURAL SUPPORTS AND MISCELLANEOUS (0.105)	
Hot-rolled bars, plates, and structural shapes	pcu 3312#4	0.406		
Concrete reinforcing bars, carbon steel	pcu 3312#425	0.089		
Concrete ingredients	wpu132	0.129		
Insulation materials	wpu1392	0.353		
Total for structural supports and miscellaneous	——	**1.000**		
TOTAL–EQUIPMENT	——	——		**1.000**
Construction materials (special index)	wpusi012011	0.530	–	BUILDINGS (0.04575)
General building contractors	eeu20150006	0.470		
Total for buildings	——	**1.000**		

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CPI plant. The first columns in Table 3 list these PPIs and their BLS code numbers. The latter begin with the designation *pcu* or *wpu*.

The CEPCI inputs also include 12 labor-cost indexes (see Table 3). These indexes are also compiled by BLS. They track changes in labor rates, for such categories as Fabricated products and General building contractors. In addition, special labor-cost indexes are included for technical specialties, such as engineers and designer-drafters. Except for the last two, which are *pcu8711#1* and *pcu8712#4*, all of the labor-cost index numbers begin with the letters *ecu* or *eeu*. The large number of entries for products and labor results in a table that sprawls over three pages.

In Table 3, alongside each component and BLS index number is a component-weight factor, which has been revised (or left unchanged) in this update. As the name implies, this factor weights the change in the component's price in proportion to its importance to the sub-index or composite CEPCI. Consider the first entry: Plates, carbon steel. This component is given a weight of 0.140. This means that changes in the price of carbon-steel plate accounts for 14% of the change in the "Heat exchangers and tanks" component-index. The subtotal of weight factors equals 0.774. The balance (0.226) is contributed by the labor for fabricating these components.

Moving one column to the right, "Heat exchangers and tanks" is listed under the column heading Component Group — Level I. The weight factor in that column is 0.338. This weight factor denotes the contribution of "Heat Exchangers and Tanks" to the Equipment index, which is listed in the column Component Group — Level II. Finally, notice that the weight-factor for Equipment is 0.507, meaning that it contributes 50.7% to the composite CEPCI.

The other three major sub-indexes do not have a Component Group — Level I. Buildings has just two components: "Construction materials" and "General building contractors." These contribute 53% and 47% to the Buildings sub-index, which, in turn, contributes 4.6% to the CEPCI. The four components of the Engineering and Supervision sub-

OBSERVING THE FIVE-YEAR RULE

A rule-of-thumb limit for cost escalation is five years. This applies to all escalations of capital or operating costs. There are sound reasons for this particular time limit. Over periods of up to five years, the differences between actual prices of equipment and labor and those predicted by a cost index have been found to be small relative to the inherent error in most budget-level estimates (±20 to ±30%)[10]. Over longer periods, these deviations can become much larger. That implies that the *CEPCI* can (and should) be used to adjust costs — but only if the adjustment period is limited to five years.

An example will be used to as background for discussion. Let us say that a 700-t/d liquid oxygen (LOx) plant was built in 1970 for $10 million. How much would it cost in 2000 to construct a 700-t/d LOx plant? First, read the annual average composite CEPCI's for 1970 and 2000 from Table 1. These values are 125.7 (1970) and 394.1 (2000). Then multiply the 1970 cost by the ratio of these two CEPCI's to obtain the plant cost in 2000. Inflationary changes in the buying power of the dollar are built into the index, so don't make unnecessary currency corrections.

$$Cost = \$10,000,000 \times (394.1/125.7) = \$31,300,000 \quad (3)$$

This cost is not likely to be accurate. To begin with, during the intervening thirty years a host of changes occurred. Some of these changes involved the liquid-oxygen production process. There are steps made more efficient, steps omitted and steps added. The net result was an improvement in the production efficiency, resulting in a lower dollar-per-ton production cost.

Other changes were due to outside factors. Among the most influential of these were the many health, safety, and environmental regulations that were imposed on the CPI. These included rules affecting such diverse matters as the height of catwalk railings, the monitoring of wastewater pH, and the control of fugitive VOC (volatile organic compound) emissions from relief valves. To comply with these regulations, CPI plants had to modify their processes, install monitoring and control equipment, and hire additional professional and support personnel. For this reason alone, a comparison of the 1970 and 2000 LOx plants would fall in the "apples-and-oranges" category.

But let's get hypothetical for a moment; suppose that the 1970 and 2000 LOx plants were absolutely identical in all respects. Even then, the CEPCI-escalated cost would not be accurate. Even though these two plants would contain exactly the same number and types of all parts, the prices of this equipment and, more importantly, the labor required to install it, have escalated at different rates. The major change to the composition of the CEPCI is to increase the weight of the costs of labor and cut the weights of the equipment costs. Specifically, in the old CEPCI, Equipment contributed 61% to the composite index, while in the new CEPCI it contributes just 51%. At the same time, labor's weight factor increased from 32% in the old index to 45% in the new CEPCI. ❑

TABLE 3. REVISED CEPCI COMPONENTS AND WEIGHT FACTORS (Continued)

Component	BLS index number	Component weight factor	Component group—Level I (weight factor)	Component group—Level II (weight factor)
Administrative support, including clerical	*ecu*11142I	0.060		ENGINEERING & SUPERVISION (0.1575)
Engineering	*pcu*8711#1	0.325		
Designer/drafter	*pcu*8712#4	0.395		
Executive, administration and managerial	*ecu*11112I	0.220		
Total for engineering and supervision	———	1.000	———	
General building contractors	*eeu*20150006	0.467		CONSTRUCTION LABOR (0.290)
Heavy construction contractors	*eeu*20160006	0.317		
Special trade contractors	*eeu*20170006	0.217	———	
Total for construction labor	———	1.000		
GRAND TOTAL—*CE* PLANT COST INDEX:				1.000

TABLE 5. NORMALIZATION FACTORS

Subindex or component index	Normalization Factor
Heat exchangers and tanks	4.550
Process machinery	5.264
Pipes, valves, and fittings	5.484
Process instruments	4.499
Pumps and compressors	6.665
Electrical equipment	3.393
Structural supports and miscellaneous	4.244
Equipment	4.911
Buildings	5.764
Engineering and supervision	11.190
Construction labor	9.779
Composite CEPCI	6.363

TABLE 4. DATA FOR MARCH 2001 - BUILDINGS

Component	Weight Factor	Base PPI	Current PPI	PPI Ratios x 100		
				Unadj.	Adj.	Weighted Product
Construction material	0.530	144.1	142.3	98.8	98.8	52.34
General. bldg. contractors	0.470	17.22	17.50	101.6	30.9	14.52
Total — before normalization:						66.86
Total — after normalization (normalization factor = 5.764):						385.4

index contribute to that category, while the Construction Labor sub-index has three components. The "Engineering and supervision" and "Construction labor" sub-indexes account for 15.8% and 29.0% of the composite CEPCI, respectively. These weight factors are entered into an Excel spreadsheet that is used to calculate the composite CEPCI and sub-indexes.

Normalizing the index

Also entered into this spreadsheet, in protected squares, for each component is the base value of the Producer Price Index. This base value is the arithmetic mean of the twelve monthly values of this PPI for 2000. Thus, we can say that the base date of the revised CEPCI is Year-2000. On Table 2 this is the last line augmented with the values for the component-indexes. We believe that selecting a year's worth of data allows for a broader base than a single month.

At this point, the data entry is correct, but the results make no sense, unless the data are normalized. The PPIs do not all start at 100 in 1959–1961, which is the historical base of the index. (PPIs are given a value of 100 on the month that the series begins.) Also, labor costs are given in units of dollars per hour.

TABLE 6. DISCONTINUED BLS PRODUCER PRICE INDEXES AND THEIR REPLACEMENTS

Discontinued Producer Price Index		Replacement Producer Price Index	
Number	**Name**	**Number**	**Name**
*wpu*10170611	Standard pipe, carbon	*wpu*10170618	Line and std. pipe and oil country tubular goods, etc
*wpu*10170622	Pressure tubing, welded, carbon	*wpu*10170628	Pressure tubing, carbon
*wpu*10170624	Mechanical tubing, welded, carbon	*wpu*10170629	Mechanical tubing, carbon
*wpu*114105	Other compressors	*wpu*114111	Other compressors and vacuum pumps
*wpu*10720112	Bulk storage tank, 6,000 gallons or less	*wpu*10720104	Storage and other non-pressure tanks
*wpu*10720113	Bulk storage tank, over 6,000 gallons	*wpu*10720104	Storage and other non-pressure tanks
*wpu*10720138	Custom tanks, 3/4 in. and less	*wpu*10720136	All other tanks and vessels,custom-fabricated at factory
*wpu*10720147	Petroleum storage tanks	*wpu*10720104	Storage and other non-pressure tanks
*wpu*10720148	All other customized tanks, field assembled	*wpu*10720152	Metal tanks and vessels, custom fabricated and field erected
*wpu*11660412	Chemical mixers	*wpu*116604	Chemical industry machinery
*pcu*3312#41511	Structural steel shapes	*pcu*3312#4	Hot rolled bars, plates, and structural shapes
*wpu*114904	Parts & attachments for valves & fittings	*wpu*114903	Metal pipe fittings, flanges, and unions
*pcu*3312#453	Stainless steel plates	*pcu*3312#45	Plates and structural shapes, stainless

TABLE 7. WEIGHT FACTORS AS REVISED

Component or component group	PPI No.	Weight factor original	Revised
Prepared paint	*wpu*0621	0.028	0.024
Hot-rolled bars, plates & structural shapes	*pcu*3312#4	0.382	0.406
Concrete reinforcing bars, carbon steel	*pcu*3312#425	0.077	0.089
Concrete ingredients	*wpu*132	0.117	0.129
Insulation materials	*wpu*1392	0.396	0.353
Engineering	*pcu*8711#1	0.330	0.325
Designer-drafter	*pcu*8712#4	0.470	0.395
Executive, administrative, and management	*ecu*11112I	0.140	0.220
General building contractors	*ecu*20150006	0.334	0.467
Heavy construction contractors	*ecu*20160006	0.333	0.317
Special trade contractors	*ecu*20170006	0.333	0.217
Heat exchangers and tanks	grouping	0.370	0.338
Process machinery	grouping	0.140	0.128
Pipes, valves and fittings	grouping	0.200	0.190
Process instruments	grouping	0.070	0.105
Pumps and compressors	grouping	0.070	0.064
Electrical equipment	grouping	0.050	0.070
Structural supports and miscellaneous	grouping	0.100	0.105
Equipment	grouping	0.610	0.507
Buildings	grouping	0.070	0.046
Engineering and supervision	grouping	0.100	0.158
Construction labor	grouping	0.220	0.290

There has to be some computational adjusting to make the series continue.

Every month, the latest values of the component PPIs are entered into the spreadsheet. For each component, the ratio of the current PPI and the base PPI is multiplied by the weight factor. When this calculation has been made for all the components of a sub-index, the results are added. This sum becomes the current value of the sub-index. Lastly, each of the sub-indexes is multiplied in the spreadsheet by a "normalization factor" that has been selected such that the resulting value of each revised sub-index for January 2001 is exactly equal to the value of the corresponding old index for January 2001. This normalization process ensures that the old and revised indexes will have a seamless transition.

If that was a little hard to understand, we present a simple example to illustrate the CEPCI calculation process. Consider the Buildings sub-index for the March 2001. The components, their weight factors, and their PPIs are shown in Table 4. The weight factors are in Table 3 and the base PPI values for 2000 have been stored. The current PPI data were read from the BLS website: www.bls.gov/data/home.htm. The unadjusted ratio is (current PPI)/(base PPI). General Building Contractors is a labor cost, so it is multiplied by a productivity factor (0.3040 in March 2001).

The Weighted Product is the adjusted PPI ratio multiplied by the weight factor. The sum of these weighted products is shown both before and after normalization. Again, the normalization (splicing) factor is the ratio of the Buildings sub-index calculated via the old CEPCI to the revised sub-index. Finally, the post-normalization value, 385.4, is the Buildings sub-index for March 2001. The splicing factors are stored in the spreadsheet and they were worked out to make sure that the index continues without a discontinuity. Table 5 is a list of normalization factors.

What was revised?

There are more compelling reasons to revise the CEPCI than the centennial of this magazine in 2002 or the start of a new century. Progress over the last 18 years is the main impetus for a fresh look. Here are some of the reasons for an update, and some of the actions put into the revised index.

1) The BLS no longer reports 14 of the PPI inputs to the old CEPCI. Consequently, each of these inputs had to be frozen at the value last reported by BLS. Needless to say, a frozen PPI contributes nothing to the index-updating process. We were able to find suitable replacements for these discontinued PPIs. These replacements are listed in Table 6.

2) Two of the labor categories in the old CEPCI (Draftsman and Typist) are

TABLE 8. NEW *CE* PLANT COST INDEXES: JANUARY – SEPT. 2001

Index/Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.*	Aug.*	Sept.*
CE Plant Cost	395.4	393.6	394.4	393.2	393.8	393.9	393.8	394.2	393.7
Equipment	439.6	437.0	437.7	437.7	436.5	436.5	436.8	436.8	436.1
• Heat exchangers and tanks	367.7	365.6	365.7	360.3	361.3	361.3	363.6	363.0	364.6
• Process machinery	441.6	441.1	442.1	441.5	442.1	443.3	442.6	440.9	431.1
• Pipes, valves and fittings	551.2	544.1	545.8	551.6	549.0	547.8	547.0	540.4	542.4
• Process instruments	368.1	365.8	365.8	364.5	363.8	362.9	361.0	360.2	357.1
• Pumps and compressors	672.6	670.3	673.0	673.3	675.8	674.0	673.3	693.1	695.3
• Electrical equipment	340.2	340.8	341.7	342.1	342.6	342.0	341.8	341.1	341.1
• Structural supports and misc.	416.3	414.2	414.3	413.4	413.6	415.9	415.7	415.8	416.6
Construction labor	300.6	300.0	301.1	299.1	300.8	301.5	301.2	305.3	304.7
Buildings	385.4	385.6	385.6	385.2	389.1	389.1	386.6	387.8	387.4
Engineering and supervision	341.3	341.1	342.5	343.7	343.4	342.8	342.2	342.2	341.5

* The index values for this month are preliminary

TABLE 9. COMPARISON OF *CE* PLANT COST INDEXES: JAN.–SEPT. 2001

| Month	*CE* Index		Equipment		Const. Labor		Buildings		Engr. and Supv.	
	revised	older	revised	older	revised	older	revised	older	revised	older
Jan.	395.4	395.4	439.6	439.6	300.6	300.6	385.4	385.4	341.3	341.3
Feb.	393.6	395.1	437.0	438.8	300.0	301.4	385.6	385.7	341.1	341.0
Mar.	394.4	394.3	437.7	438.1	301.1	300.0	385.6	383.9	342.5	341.7
Apr.	393.2	394.5	436.5	439.6	299.1	297.6	385.2	382.7	343.7	341.4
May	393.8	395.4	436.5	439.7	300.8	299.8	389.1	386.6	343.4	342.0
June	393.9	395.1	436.5	439.0	301.5	300.2	389.1	386.2	342.8	341.7
July(P)	393.8	395.3	436.8	439.1	301.2	301.6	386.6	385.2	342.2	341.5
Aug.(P)	394.2	396.3	436.1	439.7	305.3	303.9	387.8	386.7	342.2	342.1
Sept.(P)	393.7	396.8	435.7	439.9	304.7	305.4	387.4	387.4	341.5	341.8
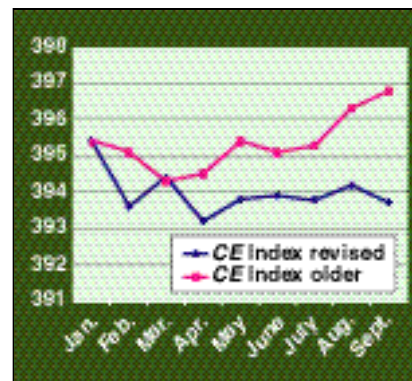
FIGURE 2. The revised CEPCI shows a slight tendency to decline while the old index is rising during 2001
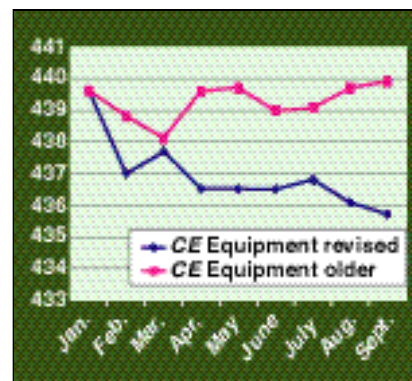

FIGURE 3. The revised Equipment subindex shows a steady decline while the old Equipment subindex is nearly constant during 2001

no longer relevant. These days, drafting is typically done via CAD (computer-assisted drafting) programs, not on blueprints, and today's engineering-design firms employ hardly any typists. PCs on everyone's desk have replaced most typists. Hence, we replaced these labor categories with those that more accurately reflect the 21st-century labor mix. These new job categories are in Table 3 under the Engineering and Supervision sub-index.

3) Another area needing modernization was the set of component-weight factors. For the most part, these reflected the composition of the typical CPI plant circa 1960 or 1970. We surveyed roughly twenty CPI companies, engineering firms, index publishers and technical organizations to obtain the information necessary to update these weight factors. As a result of their responses, we modified all of the Level I and Level II weight factors, and several of the component weight factors [7].

Table 7 displays the weight factors that were changed, showing both the old and revised values. We had to adjust components (such as Prepared Paint), Level I component groups (Heat Exchangers and Tanks), and Level II component groups (Equipment). The new weight factors for each entry (whether revised or left unchanged) are listed with their position on Table 3. For instance, the revised weight factor for Heat Exchangers and Tanks (0.338) tells us that this component group accounts for 33.8% of the Equipment sub-index, not 33.8% of the composite CEPCI.

The differences between the original (1982) and revised (2001) weight factors are not large. Still, there is a definite trend away from equipment-oriented components and toward labor-cost-oriented components. The Equipment sub-index weight factor decreases from 0.61 to 0.507, while the factor for Construction Labor in-

creases from 0.22 to 0.29. The relatively slow growth in equipment prices (as tracked by the PPIs) over the past few decades account for much of the drop in the equipment component weight factors. This slow price growth is due to improvements in domestic fabrication processes, the importing of foreign-made equipment, and other factors. On the other hand, the relatively large increases in labor costs (both technical and non-technical) are attributable to the usual influences — inflation, skilled personnel shortages, and labor-management bargaining agreements.

4) Lastly, the annual productivity growth rate was revised to better reflect both short- and long term changes in construction-labor productivity. As this growth rate is the key input to the productivity factor, it had to be selected with care. Unfortunately, while the BLS compiles labor-productivity data for 100% of the manufacturing sector,

THE VAPCCI INDEXES

Several cost indexes appear on the Economic Indicators page of this magazine. One set of that relies heavily on BLS inputs consists of the Vatavuk Air Pollution Control Cost Indexes (VAPCCIs). These are custom-designed for adjusting the equipment costs of air-pollution control systems. They were created in 1994 and first published in *CE* in late 1995 [*11*]. These quarterly indexes presently cover 11 control-equipment categories. The first-quarter of 1994 is the base date for the VAPCCIs. All indexes have been arbitrarily assigned a value of 100.0 for that base date. Table 10 lists the annual VAPPCIs for 1994 through 2000. Each annual index is the average of the quarterly indexes. Year 2001 can be found on the back page of this issue. Reference [*11*] is posted at www.che.com/CEEXTRA. ❑

TABLE 10. VATAVUK AIR POLLUTION CONTROL COST INDEXES							
Control device	Year						
	1994	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Carbon adsorbers	101.2	110.7	106.4	104.7	103.6	100.8	108.0
Catalytic incinerators	102.0	107.1	107.0	107.7	106.5	102.9	114.3
Electrostatic precipitators	102.8	108.2	108.0	108.8	109.2	101.2	101.1
Fabric filters	100.5	102.7	104.5	106.2	109.5	111.7	113.0
Flares	100.5	107.5	104.9	105.8	103.6	99.4	104.3
Gas absorbers	100.8	105.6	107.8	107.6	109.7	110.9	112.9
Mechanical collectors	100.3	103.0	103.3	103.9	111.0	119.6	121.8
Refrigeration systems	100.5	103.0	104.4	106.1	107.6	105.7	106.1
Regenerative thermal oxidizers	101.4	104.4	106.3	107.9	108.9	108.1	109.0
Thermal incinerators	101.3	105.9	108.2	109.4	110.5	108.1	107.9
Wet scrubbers	101.3	112.5	109.8	109.0	109.7	108.8	113.8

FIGURE 4. There is no discernable difference in Construction Labor subindex in 2001 between the revised and the older version
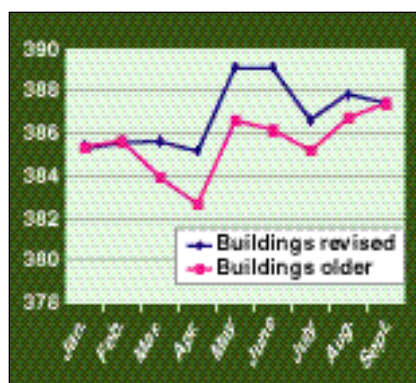

FIGURE 5. There is no significant difference in Buildings Cost subindex in 2001 between the revised and the older version
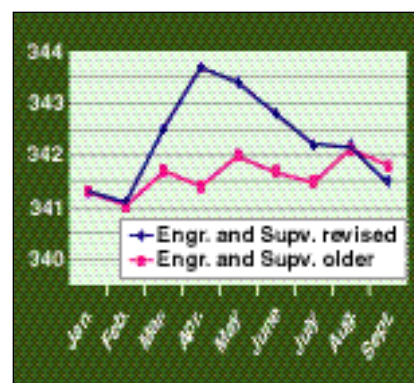

FIGURE 6. There is a no systematic difference in Engineering and Supervision Cost subindex in 2001 between the revised and the older version

it does not compile construction-labor productivity data. Our efforts to obtain these data from other sources, governmental and private, failed.

However, based on BLS's recommendation, we have decided to use the labor productivity for the Total Nonfarm Business sector. According to BLS, this sector, "represents changes in the productive efficiency of a sector that includes service-producing industries and the construction and mining industries, as well as manufacturing" [*8*]. The annual productivity growth (measured in output per hour) for the Private Nonfarm Business sector was 2.3% for the 1995–98 period and 2.2% for the 1947–98 period [*9*]. (The most recent year for which these productivity data are available is 1998.) Thus, the short and long term compound growth rates for this sector are virtually equal. We have selected the 2.2% annual growth rate to use in the productivity factor calculation. This re-

places the 1.75% rate used in the old CEPCI computation. (Coincidentally, the 2.2% rate is close to the arithmetic mean of 1982's 1.75% and the original 2.5% rate used [1963 to 1981] in the CEPCI calculation.)

Something old, something new

In this ending section, we present the new indexes and display them side-by-side with the indexes they've replaced. The achieved objective has been to improve and update the CEPCI but not change its basis.

For this comparison we prepared Table 8. This table lists the CEPCI composite, along with its sub-indexes and component-indexes for the months of January through September 2001. Note that the indexes for July and August and September are still preliminary. That is, at the time of the writing of this article (mid-December) the BLS inputs for the months following June were not final.

While it's a bit risky to draw inferences from preliminary results, we can indicate some trends, or lack thereof. The CEPCI composite decreases from a January high of 395.4 to 393.7 in September. But in the meantime, it oscillates within that range. The Equipment sub-index shows a modest decline while Construction Labor increases. Meanwhile, the Buildings, and Engineering and Supervision subindexes stay almost constant during these nine months.

This is interesting, especially when we remember that these last three subindexes are heavily weighted with labor-cost components. That is, any changes — increases or decreases — in these labor components have been discounted by the productivity factor. Despite that dampening effect, the sub-indexes have grown, while the composite CEPCI and Equipment sub-index have decreased. A good part of that decrease is due to the steep drop during this pe-

riod in some of the steel-related PPIs that are key inputs to the Equipment components. These include such components as stainless steel plates (dipped 7.4%) and carbon steel sheet (declined by 6%). Because the Buildings, Engineering and Supervision, and Construction Labor sub-indexes are influenced much more by changes in labor costs than in basic steel prices, they usually increase over time.

Finally, the revised and old (previous) CEPCIs for January through September 2001 are compared in Table 9. This table, along with Figures 2 through 6, displays the respective CEPCI composites and the four major sub-indexes. Notice that the January entries in Table 8 are identical. This is not mere coincidence. As explained earlier, the revised CEPCI composite and sub-indexes for January have been purposely equated with the their counterparts in the old CEPCI. This normalization has been done to effect a seamless transition between the two CEPCIs.

While there isn't space in this article to compare all five indexes, we can focus on one, the CEPCI composite. From equality in January-March, the respective composites begin to diverge. By September, the composites have drifted away from each other by 2.9 points. The revised index shows a little deflation and the old index shows a little inflation. We can allow one observation: The old and new CEPCIs are responding to the same economic inputs — for instance, the PPIs and productivity factor. But, because of the revisions we've made, the indexes are responding to them differently.

Some final thoughts

We hope that the revised CEPCI is a much better fit than the previous version, with respect to how accurately it tracks changes in CPI plant-construction costs. Nevertheless, the CEPCI cannot be applied unthinkingly; there are limitations to its use.

In general, the CEPCI can be used confidently, to escalate plant costs, but only for periods no greater than five years (See box p. 66). Such limitations merely remind us of the true nature of indexes. That is, like all other indexes, the CEPCI is merely a model — a representation of equipment and labor pricing schemes. Over one extended period, the CEPCI might track these prices quite closely. But over the very next period, it might deviate from them significantly. Needless to say, do not escalate plant costs blindly via the CEPCI (or any other index) if you can access current costs. Still, when there is not enough time or resources to obtain the latest costs, the CEPCI and its components — easy to use, easy to understand, and custom-designed for the CPI — provide an excellent substitute. ■

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• Richard Vishanoff (Marshall & Swift, Los Angeles, Calif.)
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