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2019

Front-End / Conceptual Estimating Yearbook

18TH EDITION

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2019 Front-End / Conceptual Estimating Yearbook

18TH ANNUAL EDITION

- Front End / Conceptual CAPEX Estimating Issues
- Capital Cost Estimating Fundamentals
- Capital Cost Estimating Methods
- Benchmarking Data
- Exponent / Cost - Capacity Equations
- Ratio / Percentage Factors and M.E. Multipliers
- Square Foot / M2 Unit Prices (60 + Building - Facility Types)
- Unit Prices (Labor & Materials) 1,000 + cost line items
- Location Factors, Engineering / CM Fee's, Labor Rates
- Process Equipment Prices (8 5+ pages)
- Front End / Semi-Detailed Estimating Systems

Compass International Consultants Inc.

Morrisville, Pennsylvania, USA

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ABOUT THE FIRM

Compass International Consultants Inc. (C.I.C.I) was founded in 1992 and is a provider of Estimating Services, International Construction Cost Data, Location Factors, Estimating Training Seminars, Value Engineering, Production and Review of Claims, Estimating Support and a provider of Global Conceptual Construction Economic Cost Data. Compass International is backed by an excellent team of experienced Cost Engineers, Cost Estimators, Planners, Civil / Mechanical / Chemical Engineers and Economists.

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ACKNOWLEDGEMENTS

This data source is the result of more than 20+ year's research and data collection. The information contained in this data source was collected from more than 100 + completed CAPEX projects (Refinery, Chemical and Manufacturing facilities) located in North America, the UK, Mainland Europe, Asia, Africa and South America valued between $0.30 million to over $3 billion. The data is for the most part based on Compass International's cost library, augmented with latest cost and labor data from International Development Banks and Agencies, EU Commission Reports, various Country National Libraries and Bibliotheques from around the world, various Government Information Agencies, Global Quasi-Governance Organizations, an assortment of Government Trade Promotion Departments / Labor Departments, numerous trade magazines, hourly and annual salary rates from US / Overseas labor organizations and newspaper articles, professional society articles, an assortment of technical magazine articles, various international almanacs and directories, reference books, internet data and various cost – construction proposals and bids from contractors and engineering firms together with related journals, the cost models and tables have also been augmented by a number of personal estimating libraries (that in some cases are very recent), this information has been audited, expanded upon, modified and calibrated and refined to today's construction methods and installation applications. We would like to express our sincere thanks to the many engineers, contractors, vendors and other individuals (friends and colleagues) too many to mention who have given freely of their advice, input, time and knowledge so that this data source could be produced for the benefit of engineering and construction professionals that have an interest in this subject matter. We welcome any comments or data that could be used in future updates to make this database more complete and accurate.

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General Information: Introduction to CAPEX Estimating

Introduction to Front End / Conceptual Estimating: *"A Front End / Conceptual estimate is an estimation of the cost of a proposed CAPEX project based on initial conceptual engineering and design data, even though the specific details are not clearly revealed or specified at this early stage of the proposed CAPEX project. An all-inclusive value is required to determine the viability of the proposed undertaking."*

The completion of a front-end estimate / conceptual estimate is usually the first step in the CAPEX Budgeting / Estimating process. This publication has been compiled to assist all construction professionals with an annual reference guide that will help them with "quick" reasonably accurate construction prices for work associated with chemical plants, refineries, manufacturing facilities and other related industrial plants. A vast number of challenges and hurdles remain in place for "Process / Manufacturing / Chemical" companies (and their decisions to build new / revamped facilities): as we look into the future as of late 2018, the issues to be faced in 2019 and beyond include numerous issues (that have financial, construction and operating cost consequences) that will need to be gauged and planned for, if the decision is made to proceed with the EPC effort. The Process / Manufacturing / Chemical industry as the engineering / construction professionals knew it in the early years of the last decade will have changed dramatically in the next two or three decades. Emerging economies such as China, India, Brazil and South Korea to name but a few will continue to forge ahead in developing their R & D and manufacturing bases, there is an increasing anxiety in some of the more developed nations as to how this will all play out and what impact this manufacturing / economic "sea change" will have on the future employment opportunities, facility costs and engineering / construction activities in Western Europe, North America and around the world. Hopefully, this publication and its' future updates will assist the reader in navigating and understanding the dynamics of this situation, and the associated engineering / construction related costs specific to Process / Manufacturing / Chemical facilities.down all other legislation topics.

The US construction industry will continue to struggle in 2019 with a shortage of skilled craft workers.

THE GENERAL FORECAST FOR 2019 AND BEYOND

(Specific to the Process / Manufacturing / Chemical Industry and to the construction of these facilities).

- The US construction industry will continue to struggle in 2019 with a shortage of skilled craft workers.
- The Global Enginnering, Procurement and Construction (EPC) market has had a ten year roller coaster ride. Asia, Africa and South America have

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are designed in a safe and cost effective manner. Successful capital EPC projects are deemed successful if they meet the legged stool metric previously referred to. It must be remembered that the end use of a capital project is to increase product sales, beat competitors to the market place, to operate the facility at lower unit operating costs and to be flexible and sustainable for the future growth goals of the owners operating unit (future expansion added operating units or addition production trains need to be considered- going forward). A capital cost estimate, to be effective management tool (and a project control tool) for implementation and future cost management and planning (consider a capital cost estimate as a road map – you start out in A and you need to get to Z). This document and an execution plan are key tools needed to get the project completed, the capital cost estimate should have line by line items (by Company code of accounts (COA) – or work breakdown structure (WBS) where possible) showing major equipment, freight costs, bulk and engineered materials together with construction labor (man hours) by discipline i.e. civil, mechanical, piping, E/I, etc including indirect build up such as engineering costs and man hours, construction management, general conditions and contingency etc.. This data is needed to pragmatically establish, possible long lead major equipment items, extent of bulk materials, field labor requirements. Do we need to establish a concrete batching plant, design staffing needs, construction management needs, spare part requirements and period / timing / duration requirements? The EPC project team requires "estimating details" as early as possible in the execution phase to plan the purchasing effort (buy out) and execute the project, perhaps by various work packages. Capital Cost Estimates can be (1) early front end conceptual, (2) preliminary a decent amount of engineering has been completed, or (3) definitive / lump sum at least 50% of the required engineering effort has been compiled. These estimating types are of course reliant on the quality of information provided and the estimating effort required to produce them. Cost estimating procedures vary from down and dirty relatively quick (and not very accurate) ratio / percentage factoring to highly developed "details oriented" computerized capitalized cost estimating / scheduling systems that can produce substantial amounts of capital cost estimating and in some situations engineering data. If the above described methods are correctly utilized, they can generate very precise and detailed capital cost estimates that have a high degree of creditability and more importantly can forecast the final cost of the CAPEX project.

A capital cost estimate is not over and done with when a project management / engineering review has approved the CAPEX capital cost estimate.

To drive home a basic point again, it should be kept in mind that there are three basic types of estimates, (A) Front End Estimate (OOM, preliminary, conceptual etc) perhaps a good amount of basic process design has been compiled - PFD's, plot plans, we know the number of major equipment items, we know we need offsite storage, we know we need loading areas, we know we need a warehouse, however the detailed design has not been completed or it may only be less than 20%. (B) AFE Funding / Preliminary (perhaps a hybrid of A and C, and (C) Detailed Estimates (Lump sum bids, GMP's, Design / Build etc) are based on a lot more definition, the design deliverables may be 30% - 60% complete, we have a priced out major equipment list, we have detailed quantity take-off's, we have plot plans, general arrangement drawings and the P&ID's could be well advanced. Precise (bearing in mind the level of design work that has been compiled) and timely capital cost estimating preparation is a very important aspect to successful project execution and profitable projects. Typically the decision to execute the EPC project cannot proceed without management approval of

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	MATERIAL	%	LABOR	%	TOTAL	
(D) OFF SITES OSBL (CONTINUED)						
Piping Systems	88,745	10.05%	93,664	10.61%	182,409	
Electrical Systems	40,453	4.58%	36,553	4.14%	77,006	
Instrument / Controls	58,894	6.67%	14,640	1.66%	73,534	
Paint / Insulation	18,547	2.10%	19,336	2.19%	37,883	
Fire Protection / Safety	15,453	1.75%	16,677	1.89%	32,130	
Loading Facilities	362,447	41.06%	79,774	9.04%	442,221	
(D) TOTAL DIRECT MAT & LABOR	**1,627,482**	**84.38%**	**491396**	**55.67%**	**2,118,878**	
(E) INDIRECT WORK						
Trade Supervision / Foreman / Gangers etc.	16,594	1.88%	66,641	7.55%	83,235	
Consumable supplies	29,392	3.33%	2,383	0.27%	31,776	
Small Tools (items less than $200 per item)	26,921	3.05%	2,207	0.25%	29,128	
Site Establishment / Trailers / Temp Offices.	48,899	5.54%	25,156	2.85%	74,055	
Safety / Training	3,089	0.35%	7,503	0.85%	10,592	
Constr. Equipment costs. Rental / Owned.	12,092	1.37%	65,758	7.45%	77,850	
Constr. Equipment Repairs etc. / Fueling.	4,855	0.55%	9,268	1.05%	14,123	
Material Mgmt / Logistics / Field Support	19,860	2.25%	10,592	1.20%	30,452	
Testing Activities	1,854	0.21%	1,324	0.15%	3,178	
Site Clean Up	3,707	0.42%	8,827	1.00%	12,534	
Expense items (Demo / relocations)	11,739	1.33%	14,387	1.63%	26,127	
Sales Tax (optional cost item could be excluded)	48,723	5.52%	0	0.00%	48,723	
TOTAL INDIRECT WORK	**227,726**		**214,044**		**441,770**	
TOTAL D & I (D+E) OSBL	**1,855,208**		**705,440**	**1**	**2,560,648**	
(F) DETAILED DESIGN D.D.& S. FOR OSBL						
EPC Detailed Design					136739	5.34% Of D&I
Construction Mgmt					82,197	3.21% Of D&I
Home Office support / field coordination					10,243	0.40% Of D&I
Travel Costs					19,205	0.75% Of D&I
Owner Project Eng / CM					11,523	0.45% Of D&I
Plant C.M. / Eng Support					16,644	0.65% Of D&I
Plant Gen Conditions					8,450	0.33% Of D&I
Consultants / Miscellaneous Costs					12,291	0.48% Of D&I
TOTAL (D.D.& S) ISBL					**297,291**	
TOTAL OSBL (D+E+F)					**2,857,939**	
Total w/o contingency					24,687,401	
Contingency 10% (range 5% - 20%)					2,468,740	10.00% Of Total
TOTAL (INCLUDES ISBL & OSBL)					**$27,156,142**	

All % are related to M.E. values.
Note 1. Vendor assistance, start up, I/C programming and initial chemicals

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Table 31

UREA - NITROGEN - NITRIC ACID - FERTILIZER FACILITY - 425 TONS / DAY PRODUCTION
LOCATION MID WEST USA - 2015 COST BASIS
UNION LABOR (26 MONTH CONSTRUCTION EFFORT)
80 ACRE SITE WITH MINIMAL SITE CLEARING

#	CATEGORY	M-H'S	$ TIC COST	$ COST / HOUR	REMARKS
1	Engineering / Detailed Design	68,562	10,205,995	$148.86	includes profit on bill out rate
2	OH / GA Profit - Fee / CAD / Repro / Admin HO Support Staff		3,977,532		39% of # 1
3	Procurement of Major Equipment, including 5 # Field Erected Tanks & pre-fab piping	74,865,775			259 Tagged M.E. items (excludes instruments) approx shipping weight = 19,750 tons
4	Construction Direct Labor (all trades)	598,774	23,196,505	$38.74	Rate ranges from $32.50 for lower skills to $41.85 for electricians & pipefitters
5	Indirects (general conditions, site establishment, construction equipment, small tools, consumables, heavy lift cranes)	598,774	17,094,998	$28.55	Combined rate = $67.29
6	Construction Bulks	37,887,346			Concrete, rebar, forwork, struc steel, electrical & insulation
7	Construction tagged items (instruments / CV's)	7,648,862			Purchased by Engineering firm (1,397 #)
8	Construction In-Direct Support Labor	202,334	7,277,665	$35.97	
9	Construction Management	72,446	8,867,435	$122.40	Locals & OoTown Consultants (approx 14 individuals)
10	C M Travel / Per Diem / Site Trucks / Other field costs		3,776,347		
11	Miscl items Demo / Removals (rail spur / transmission lines)		2,788,734		
12	Barge Loading Area / Conveyors / Diverters		5,966,745		incl truck scales
13	Miscl items, Fencing, guard service, rail spur, temp roads, temp utilities & 3rd party testing		2,433,763		12 Field created P.O.'s
14	Construction contractors fee on construction pass thru		4,927,665		Construction work final a/c = $104,667,000 (4.7%)
15	Total EPCM Cost (425 Tons / Per Day - 150,000 TPY)		$210,915,366		
	COST PER TON (MILLIONS $)		**$496,270**		
	Typical CAPEX Cost Range per Ton / Day	**High**	**$596,000**		
	Typical CAPEX Cost Range per Ton / Day	**Low**	**$397,000**		
	Excludes Owner In-House Engineering & Owner general conditions & consultants				
	Excludes Front End Studies / Permitting studies				
	Excludes Initial fill & chemicals & spare parts				
	Excludes Jetty / River Intake Structure - $3.7 million				

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Table 32

ENGINEERING, PROCUREMENT AND CONSTRUCTION COSTS FOR TYPICAL $20 MILLION TO $80 MILLION SHALE – SYNGAS – CO2 - LNG – INDUSTRIAL GAS FACILITY; 2015 COST BASIS:

Costs of course vary on each and every facility;
however the typical ranges / percentage splits are as follows:

CATEGORY	LOW % RANGE	HIGH % RANGE
Engineering / Detailed Design	10% to 12%	12% to 16%
Procurement including Major Equipment	30% to 40%	35% to 50%
Construction including some bulks such as civil, site works, concrete & structural steel	30% to 40%	35% to 45%
Construction Management	5% to 8%	7% to 10%
Commissioning / Start Up	2% to 4%	3% to 5%
EPC Fee	3% to 4.5%	4.5% to 7.5%

Table 33

1 MILLION TONS PER YEAR ETHYLENE / LNG FACILITY COST MODEL
2016 US GULF COAST COST BASIS: ISBL = 81% OSBL = 19%

CATEGORY	APPROX., % SPLIT	OPEN SHOP TOTAL EPC COST PER TON LOW	OPEN SHOP TOTAL EPC COST PER TON AVERAGE	OPEN SHOP TOTAL EPC COST PER TON HIGH	UNION TOTAL EPC COST PER TON LOW	UNION TOTAL EPC COST PER TON AVERAGE	UNION TOTAL EPC COST PER TON HIGH
Major Equipment (Tagged Items)	26%		$416			$459	
Bulk Materials	16%		$257			$284	
Direct Field Labor	14%		$227			$250	
Field Labor In directs	11%		$176			$194	
Engineering Detailed Design	10%		$165			$182	
Project Management / Project Control / Procurement	2%		$29			$32	
Fees	3%		$53			$59	
Miscellaneous	5%		$81			$90	
Contingency	6%		$97			$107	
Construction Management	5%		$80			$89	
TOTAL	**100%**	**$1,187**	**$1,582**	**$1,978**	**$1,310**	**$1,746**	**$2,183**

BENCHMARKS
# of Major Equipment 250 to 300
# of Instruments 3,500 to 4,000
CY of Concrete 50,000 to 60,000
Tons of Structural Steel 6,000 to 7,000
LF of above ground pipe 450,000 to 550,000
Direct Construction Man-Hours 4,000,000 to 5,000,000
Detailed Design Hours 700,000 to 825,000

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Semi-Detailed Cost Estimating Data

The following listing of unit prices are focused on process / manufacturing CAPEX projects ranging in cost from $0.50 to $100 + million. These unit costs are for new construction, it should be noted that alteration / revamp / major renovation construction work could cost between 10% and 50% more than the values indicated in the nine listings. These unit prices are 2019 values (calibrated to mid point of year) they are based on historical data of projects completed in North America and have been adjusted to reflect pricing within the Washington DC beltway (25 - 40 mile radius). A hybrid of Union / Non-union pay scales have been used in determining labor / installation values: (The labor cost value includes a value for construction / rental equipment, i.e., 6.50%, this is for cranes, welding machines and similar types of equipment required to complete each individual task). The units include supervision, plus a profit margin of 10%. (A percentage of between 7 % – 11% - suggest 8.5% should be added to the values indicated to capture site establishment (Division 1 / Preliminaries) costs for such items as scaffolding, trailers, testing, temporary warehousing and testing etc:

GENERAL CONVERSION VALUES - IMPERIAL TO METRIC UNITS

- 1 Acre = 4,047 M2
- 1 Foot = 30.48 Centimeters
- 1 Foot = 0.3048 Meters
- 1 Meter = 39.37 inches
- 1 Meter = 1.094 Yards
- 1 Cubic Yard = 0.765 M3:
- 1 M3 = 1.31 Cubic Yards:
- 1 M = 3.28 Lineal Feet:
- 1 M2 = 10.76 Square Feet:
- 1 Hectare = 2.471 Acres
- 1 Kilogram = 2.205 Pounds
- 1 Gallon = 3,785 Cubic Centimeters
- 1 Imperial Gallon = 1.20095 US Gallons
- 1 Liter = 0.264 Gallons
- 1 Square Foot = 0.0929 M2
- 1 Mile = 1.609 Kilometers
- 1 Square Kilometer = 247 Acres
- 1 Square Yard = 0.836 M2
- 1 Yard = 0.9144 M

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Table 3

CSI DIVISION 2 & 3 FOUNDATIONS / U.G. WORK

#	DESCRIPTION	UNIT	MATERIAL	LABOR	TOTAL
1	Compaction of excavated material	CY	1.88	3.22	5.09
2	Ditto to 95%	CY	3.68	3.92	7.60
3	Excavate trench 3' wide n/e 5' deep and backfill (includes P & S)	CY	5.16	11.27	16.43
4	Excavate trench 4' wide n/e 10' deep and backfill (includes P & S)	CY	6.93	12.44	19.37
5	Excavate trench 5' wide n/e 15' deep and backfill (includes P & S)	CY	8.33	14.03	22.36
6	Piles, pre cast concrete, square 10"	LF	18.35	17.83	36.18
7	Piles, pre cast concrete, square 12"	LF	21.74	19.67	41.41
8	Piles, pre cast concrete, square 18"	LF	22.25	19.34	41.59
9	Piles, steel H section, 10"	LF	44.31	22.29	66.60
10	Piles, pipe, 12", concrete filled	LF	19.56	22.33	41.89
11	Piles, wood, untreated to 40'	LF	8.28	14.80	23.08
12	12" diameter x 10' long with rebar, no casing	EACH	108.30	265.71	374.01
13	18" diameter x 20' long with rebar, no casing	EACH	267.15	610.38	877.53
14	24" diameter x 30' long with rebar, no casing	EACH	700.33	1,026.87	1,727.20
15	36" diameter x 40' long with rebar, no casing	EACH	2,339.22	2,039.36	4,378.58
16	48" diameter x 50' long with rebar, no casing	EACH	4,620.67	3,475.54	8,096.21
17	3" Bit paving on 6" crusher run 16' wide	LF	53.42	56.00	109.42
18	4" ditto 24' wide	LF	69.31	89.04	158.35
19	Planking & Strutting to trench	SF	0.79	1.71	2.51
20	Sheet piling (20 uses)	SF	1.16	2.51	3.67
21	Sheet piling (Left in place)	SF	20.79	7.54	28.34
22	Reinforced concrete foundations, including excavation by machine, b/f, concrete, rebar and formwork, 3,000 psi. 2' x 2' x 1'	EACH	47.11	31.68	78.79
23	Ditto 3' x 3' x 2' including excavation by machine, b/f, concrete, rebar and formwork, 3,000 psi.	EACH	198.88	132.03	330.91
24	Ditto 3' x 3' x 3' including excavation by machine, b/f, concrete, rebar and formwork, 3,000 psi.	EACH	298.33	198.04	496.38
25	Ditto 4' x 4' x 2' including excavation by machine, b/f, concrete, rebar and formwork, 3,000 psi.	EACH	350.67	237.65	588.32
26	Ditto 5' x 5' x 2' including excavation by machine, b/f, concrete, rebar and formwork, 3,000 psi.	EACH	554.79	369.80	924.59
27	Ditto 6' x 6' x 2' including excavation by machine, b/f, concrete, rebar and formwork, 3,000 psi.	EACH	994.44	660.13	1,654.57
28	Ditto 8' x 8' x 3' including excavation by machine, b/f, concrete, rebar and formwork, 3,000 psi.	EACH	2,119.72	1,410.14	3,529.86
29	Ditto 10' x 10' x 3'	EACH	2,826.30	1,901.19	4,727.48
30	Foundation, underpinning, 5' deep, (machine excavation – tremi - hand packed concrete	LF	324.88	423.67	748.56
31	Foundation, underpinning, 10' deep, (machine excavation – tremi - hand packed concrete	LF	440.41	524.21	964.63

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Tubing Stainless Steel

316 PHARMACEUTICAL GRADE PIPING COST / LF OF INSTALLED PIPE (INCLUDES PIPE & FITTINGS, EXCLUDES VALVES):

DIA.	MATERIAL / LABOR COST PER LF	MATERIAL / LABOR COST PER M
1"	$90	$294
1.50"	$100	$329
2"	$145	$474
3"	$162	$530

Valves - Installation Man Hours

THE FOLLOWING MAN-HOURS APPLY FOR ALL MATERIAL TYPES

DIAMETER	MAN HOURS
2"	2.50
3"	3
4"	4
6"	5
8"	7
10"	10
12"	12/16

Valves - Approximate Cost: use multipliers / calibration factors shown earlier for different material types, note these indicated material costs can sometimes be discounted by as much as 35% - 65% for orders greater than 10 /12 valves.

Automatic Sprinkler System

DRY SYSTEM	WET SYSTEM
$2.65 – $4.25 / SF	$2.35 – $3.85 / SF

Demolition & Removal of C.S. / S.S. Piping

INCLUDE HANGARS, FITTINGS & VALVES

DIAMETER	$ COST / 100 LF
1"	17.52
2"	32.51
3"	43.65
4"	58.35
6"	72.79
8"	93.26
10"	111.96
12"	138.14

Multiply values by 1.20 if pipe is insulated
Multiply by 1.12 if pipe is steam or heat traced
Note: credit the estimated cost if pipe is sold for scrap.

Carbon Steel

150 # RATING:

DIAMETER	BALL	BUTTERFLY	CHECK	GATE	GLOBE
2"	$539	$1,216	$768	$900	$1,052
3"	$629	$1,238	$1,001	$1,232	$1,379
4"	$798	$1,539	$1,518	$1,640	$2,101
6"	$1,596	$2,463	$2,128	$2,395	$3,373
8"	$3,069	$5,310	$3,814	$5,209	$6,203
10"	$5,974	$6,219	$5,633	$6,232	$12,854
12"	$7,997	$7,975	$7,145	$7,764	$17,218

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/ Microchip facilities in piping / tubing applications such as clean in place (CIP), Steam in Place (SIP), Water for Injection (WFI) and other critical finished product lines. It is used to mitigate contamination (bacterial build up), Stainless Steel 316 L is used extensively. The welding approach utilized is where all the completed welds and the internal surface of the pipe / tube is required to be joint free / entrapment-free internally to prevent any bacterial contamination to the finished product. Full penetration (100%) welds should be aimed for. It is important to understand that any gaps, fissures, fractures including any imperfect weld joints can entrap the product / fluid flowing through the pipe / tubing. If any gaps, fissures, fractures are present they can develop into a haven for future problems and possible product contamination. Automated welding is many times utilized to lower welding production costs i.e. the main element being the cost of employing a workforce (labor costs), however the cost of purchasing the welding equipment together with its subsequent maintenance costs can be substantial, neverthe less automated welding is usually the best avenue to proceed on, on major welding projects. The best example of this is in ship building, just about all the welding is done using an automated process. Orbital welding is used in Pharmaceutical, Aerospace, Microchip and other Hi-Tech industries. Orbital welding uses the Gas Tungsten Arc Welding (GTAW) methodology; it is used primarily on small-bore piping and tubing 2" diameter and below. Stainless Steel 316 L and some other alloys that work well in extreme / harsh operating conditions are usually the specified materials that are utilized. Other industry sectors that are embarking on orbital welding in their construction process include:

- Food Production
- Dairy (Milk, Butter and Cheese production)
- Brewery / Beverage
- Nuclear / Conventional (Power Facilities)
- The Petro – Chemical and the Offshore Oil and Gas sector

These industry sectors look at this approach as a practical and cost effective opportunity for welding small bore stainless steel piping and tubing. Orbital welding makes available a process to make sure construction productivity is optimized while also ensuring that the quality of the finished weld is of a high quality.

It is important to understand that any gaps, fissures, fractures including any imperfect weld joints can entrap the product / fluid flowing through the pipe / tubing.

Fillet welding using SMAW is the welding process for connecting various carbon steel plates, vessels, sections, channels and angles together: Labor cost includes transport of welded metals to the welding area, preparation work, measuring, initial tack welding, final welding and any necessary grinding. See chart next page.

- Split of (L&M) Labor = 55% Material = 45% (Construction Equipment of 5% – 10% is included in Labor value)
- Using $59 / per hour for a welder
- For applications with a good amount of repeat work, where good productivity can be achieved multiply above values by 0.75
- For applications with small / difficult / intricate welding work multiply above values by 1.25
- Add 8% - 12% to above for vertical / horizontal applications
- Add 18% - 24% to above for overhead applications

ORDER OF MAGNITUDE PRICES:

- Cost per pound of deposited welding material = $16.95 – $26.05 (Labor and material) to use this method determine cubic content of weld.
- Weight of metal deposited in 0.25" fillet weld = 0.15 pounds per LF

DRAFT

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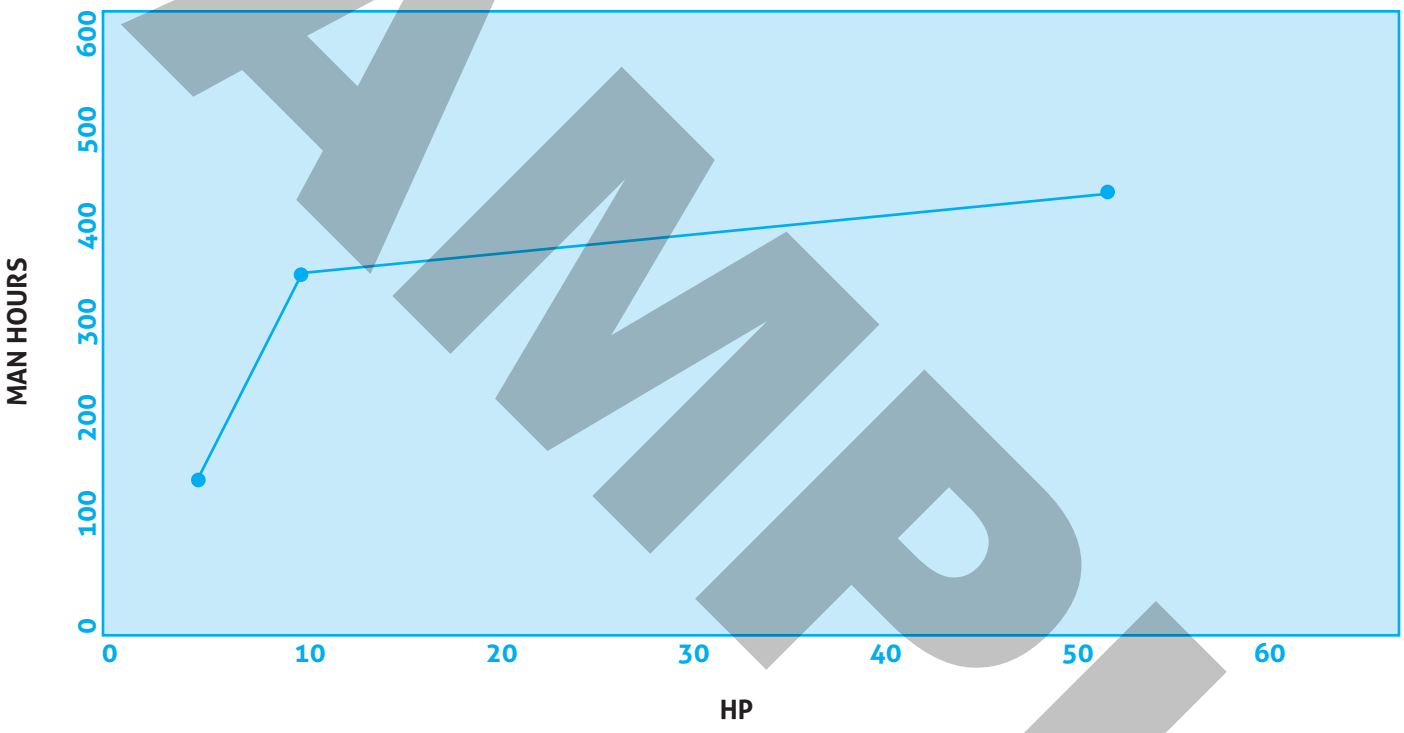
Fuel Storage Tank Fiberglass

2,500 Gallon	$2,970	4 / 6
5,000 Gallon	$4,480	6
10,000 Gallon	$11,360	16

MIXER / EXTRUDER



Furnace Gas / Oil Fired 250 PSIG CS / Alloy

DATA TABLE

MMBTU'S PER HOUR DUTY	$ COST PER UNIT TO PURCHASE DELIVERED IN SECTIONS TO SITE	$ COST PER UNIT WITH BULKS & FIELD ERECTION LABOR	$ COST PER UNIT WITH DESIGN / CM & INSPECTION
25	506,663	835,831	1,071,964
50	977,826	1,244,226	1,595,736
100	1,855,610	2,223,504	2,851,672
250	4,409,895	5,326,405	6,831,182
500	8,601,675	9,303,863	11,932,321

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Erection Man-hours

FOR CS SCHEDULE 40, 80 AND 120 PIPING; OSBL APPLICATIONS

DIAMETER / INCHES	LIFT INTO PLACE, LINEUP & TACK WELD MAN-HOURS PER LF	PRODUCTION WELD MAN-HOURS NUMBER	COLUMN A COMBINED ERECT & WELD MAN-HOURS PER LF	COLUMN A COMBINED ERECT & WELD MAN-HOURS PER M
2 screwed joints	N/A		0.30	0.98
2 welded	N/A		0.35	1.15
4	0.35	1.95	0.45	1.48
6	0.45	2.50	0.55	1.80
8	0.50	3.30	0.60	1.97
10	0.60	3.75	0.75	2.46
12	0.65	4.35	0.80	2.62
14	0.75	4.85	0.90	2.95
16	0.80	5.50	0.95	3.12
18	0.85	6.00	1.00	3.28
20	0.90	6.75	1.05	3.44
24	1.00	7.75	1.15	3.77

Erection Man-hours

FOR CS SCHEDULE 40, 80 AND 120 PIPING; ISBL APPLICATIONS

DIAMETER / INCHES	LIFT INTO PLACE, LINEUP & TACK WELD MAN-HOURS PER LF	PRODUCTION WELD MAN-HOURS NUMBER	COLUMN A COMBINED ERECT & WELD MAN-HOURS PER LF	COLUMN A COMBINED ERECT & WELD MAN-HOURS PER M
2 screwed joints	N/A		0.60	1.97
2 welded	N/A		0.95	3.12
4	0.90	1.95	1.05	3.44
6	1.05	2.50	1.27	4.17
8	1.22	3.30	1.66	5.44
10	1.55	3.85	1.75	5.74
12	1.68	4.55	1.84	6.04
14	1.75	5.35	1.97	6.46
16	1.87	6.20	2.15	7.05
18	1.95	7.10	2.30	7.54
20	2.10	7.85	2.55	8.36
24	2.30	9.45	2.75	9.02

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(B) Centrifugal Air Compressors- with motor: Add 3% for transport to site for US and overseas applications (ocean freight would increase freight cost).

(C) Centrifugal Pump, C S API 100 Deg F, 1,800 Motor

- Add 3% for transport to site for US and overseas applications (ocean freight would increase freight cost).
- If pumps and motor are skid mounted multiply above units by 0.85.
- Cost range is $26.18 - $63.67 per GPM

(D) Centrifugal Compressor C.S. – 100 PSI

- Cost range is $311 - $2,558 per HP.
- Add installation man-hours.
- Add 3% for transport to site for US and overseas applications (ocean freight would increase freight cost).

(16) CHILLER:

(A) ABSORPTION WATER CHILLERS: Installation man-hours includes unloading, unpacking, transport from temporary site warehouse to final location n/e 0.50 miles – 0.80 km, installation on base, adjusting drive alignment, calibrating and system check out. Man-hours exclude cranes, foundations, setting holding down bolts, grouting, brackets, supports, piping, cable, conduit and electrical hook-up, refer to productivity adjustments on earlier page to calibrate installation man-hours. The man-hour installation units exclude initial chemical charging, cooling liquids, refrigerant / anti freeze chemicals, M.E. passivation and cleaning (pickling) and M.E. identification / stenciling & subsequent tagging.

(B) CHILLERS, PACKAGED WATER HOT-WATER OR STEAM TYPE: Includes installation of motor and drives, controls: Excludes crane rental, foundations, setting holding down bolts, grouting, brackets, supports, piping, cable, conduit and electrical hook-up, refer to productivity adjustments on

Table 15B

CFM	$ EQUIP. COST	INSTALLATION MAN-HOURS
5,000	$416,317	420
10,000	$689,317	710
25,000	$1,250,395	1,334

Table 15C

GPM	$ EQUIP. COST	INSTALLATION MAN-HOURS
100	$6,367	420
3,000	$78,544	710

Table 15D

H.P.	$ EQUIPMENT COST	$ COST PER H.P.	INSTALLATION MAN-HOURS
25	$64,696	$2,588	38
50	$69,742	$1,395	44
100	$77,360	$774	54
250	$114,399	$458	74
500	$178,107	$356	106
1,000	$311,342	$311	184

Table 16A

RATINGS TON	$ EQUIPMENT COST	INSTALLATION MAN-HOURS
25	$22,005	30
50	$42,015	38
100	$49,683	46
250	$116,435	108

Table 16B

TONS	$ COST / EQUIPT.	MAN-HOURS PER TON
100	141,618	3.2
150	184,629	2.6
200	208,067	2.33
250	225,967	2.14
500	332,324	1.45
1,000	526,216	0.95
2,500	721,450	0.55

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50A

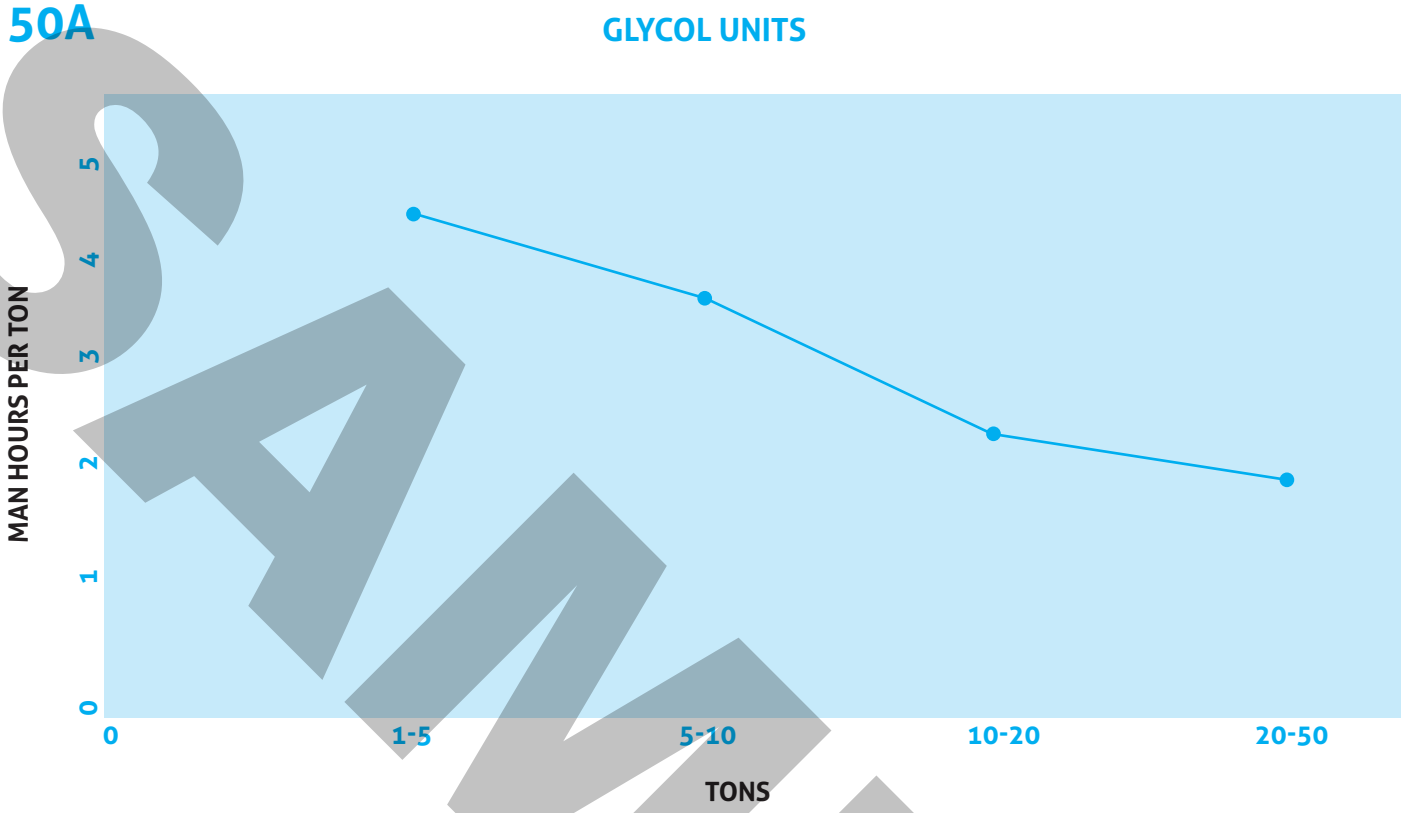

Table 51A

H.P.	APPROX WEIGHT	# OF PIECES	M.H.' S	M.H.' S PER HP
25	2,400	3 / 5	23	0.92
50	3,700	3 / 5	27	0.54
75	5,400	3 / 5	34	0.45

Table 51B

COST PER UNIT	$ COST LOW	$ COST HIGH
Cost per pound	$8.55	$11.37
Cost per Kg	$18.81	$25.01
Cost per HP	$397	$525

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OSHA safety measures, factory witness testing and any acceptance testing and operational tests, initial chemical charging, cooling liquids, "grogg" type chemicals and any scaffolding and hoisting needs. Remember there could be a need for a full time hoist operator on union projects.

Major Equipment (M.E.) / Chemical / Manufacturing facility major equipment is fundamentally all the components that are utilized in the above mentioned industries / business sectors, the (M.E.) major equipment includes items such as the following together with the "judgment" percentage to set the particular piece of major equipment described below. A description of (A), (B) and (C) is described below:

- Activators (B) / Agitators (A) / Air Dryers (B) / Air Handlers (B)
- Bag house (B) / Blenders (B) / Bins (B) / Boilers (C)
- Centrifuges (B) / Chlorine Evaporators (B) / Columns (B)
- Compressors (B) / Condensers (B) / Conveyors (C) / Crushers (B) / Crystallizers (B)
- Dearators (B) / Drums (A) / Dryers (B)
- Emulsifiers (B) / Electrical Switch Gear (B) / Evaporators (B) / Extruders (B)
- Filters (B) / Presses (B) / Furnaces (C)
- Hammer Mills (B) / Heaters (C) / Heat Exchangers (C)
- Instrument and process control equipment (B)
- Reactors (C) / Pressure vessels (B) / Pumps & Motors (B)
- Size reduction and separation equipment (B) / Scrubbers (B) / Steam Turbines (C)
- Tanks (A) / Towers (B) / Valves (motor controlled) (B) / Vessels (B)

(A) = Large / static pieces of M.E. needing relatively minimal setting hours (and minimal internal setting and aligning) 3% -7% of M.E. cost divided by $65 / hour will provide a man hour budget for setting the M.E.

(B) = Mid sized pieces of M.E. needing additional setting and requiring internal work and aligning work hours 5% -10% of M.E. cost.

(C) = Complex pieces of M.E. requiring a fair amount of assembly and setting / internal aligning hours 7% -14% of M.E. cost will provide a man hour budget for setting the M.E.

Example of a calculation to determine the cost and percentage value of installing a Reactor: 20 ton Reactor (with internals 5 ton), total weight 25 ton Purchase price delivered to site = $108,000 Labor and construction equipment to install (lift into it's final location and set and align internals, does not include piping or E&I, excludes heavy lift crane.) 2019 Cost basis:

LABOR / OTHER	HOURS	UNIT COST	TOTAL
Foreman	6	$73	438
Millwright	6	$67	402
Millwright	6	$67	402
Millwright	6	$67	402
Millwright	6	$67	402
Millwright	6	$67	402
Equipment Operator	6	$65	390
Chains / cables	1 day	$250	250
Miscellaneous l shims / rags / grease	LS	$400	400
Flatbed trailer	6	$30	180
Tractor	6	$40	240
TOTAL			**$3,908**

$108,000 divided by $3,908 = 3.6% note if you add the cost of the crane to this calculation the percentage would increase.

All major equipment items need foundations, structural steel, platforms, piping, valves, insulation, painting, electrical services, etc.. The commodities / bulk materials required will be described in the following sections. Typical break-downs of the major cost elements cost models of a Chemical / Process Plant are indicated on the next couple of pages, hopefully this data will give the reader an appreciation of how large an element of a capital cost estimate the major equipment really represents. The hours for installing major equipment typically include all the activities related to receiving, storing, lifting, moving to field location, setting, align-

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ENGINEERING / HOME OFFICE COSTS / DATA:

See chart at right. For additional data specific to installation man-hour units refer to later sections.

ESTIMATE ASSESSMENT SHEET / RATIO ANALYSIS

The capital cost estimate review sheet (see chart above and on the previous page) sets the ranges minimum and maximum for various activities, this data can be used as a data source to calibrate / compare specific key elements of a process related project, this data applies to new / green field construction applications.

- (I.S.B.L.) inside battery limits (M.E.) major equipment (T.I.C.) total installed cost
- (D.L.) direct labor

The following data / tables are a variety of man hour production units for various construction trades that can assist an estimator / cost engineer in compiling both conceptual and detailed cost estimates, for more detailed estimating units refer to Section 4.

FUNCTION / GENERAL DATA	COST / MAN-HOUR UNITS
Project Manager	$80 - $150 / hour
Architect	$85 – $150 / hour
Civil Engineer	$75 - $135 / hour
Home office engineer	$75 - $135 / hour
Estimator	$70 - $130 / hour
Designer	$55 - $90 / hour
Man-hours per item of major equipment	600 –1200 (aver 700)
Man hours per PFD	40 - 100
Man-hours per P. & I.D:	250 -500
Man-hours per plot plan / G. A.	100 –200
Man hours per ISO.	4 / 6
CAD machine bill out rate	$25 - $60 / hour
PROCUREMENT / CONTRACT / PROJECT CONTROL	
Procurement / Contracts Engineer	$60 - $100 / hour
Project Control Engineer	$70 - $110 / hour
Man-hours per material inquiry / requisition	4 - 12
Man-hours per purchase order	30 - 50
Man-hours per contract	60 –100
Inspection of M.E. item	4 – 8 / hours

Estimate Assessment Sheet / Ratio Analysis

DATA APPLIES TO NEW / GREEN FIELD CONSTRUCTION APPLICATIONS

NO.	RATIOS & PERCENTAGES	NORMAL RANGE
1	Site Works as a percentage of M.E. (I.S.B.L)	2 – 5%
2	Buildings / Structures as a percentage of M.E. (I.S.B.L)	5 – 12%
3	Piping material as percent M.E. (I.S.B.L)	20-50%
4	Labor as percent of T.I.C.	20-30%
5	Piping labor as percent of pipe material	40-125%
6	Indirect cost as percent D.L.	70-125%
7	Piping labor as percent D.L.	10-55%
8	Typical M.E. Multiplier to T.I.C.	3.0 – 5.50 (Typical average 4.00) Refer to Benchmark Data.
9	Instrument material as percent M.E. (I.S.B.L.)	15-20%
10	Electrical work as a percentage of M.E. (I.S.B.L)	7 – 12%
11	Electrical labor as a percentage of M.E. (I.S.B.L)	10 – 20%
12	Insulation work as a percentage of M.E. (I.S.B.L)	3 – 5%
13	Field Establishment as a percentage of field in-directs	4 – 9%
14	Small tools / consumables as percent of D.L.	0.15 – 2.25%
15	Scaffolding as percent of D.L.	0.5 – 2%
16	Spare Parts	5% to 7.5% of major equipment on complex process facilities

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