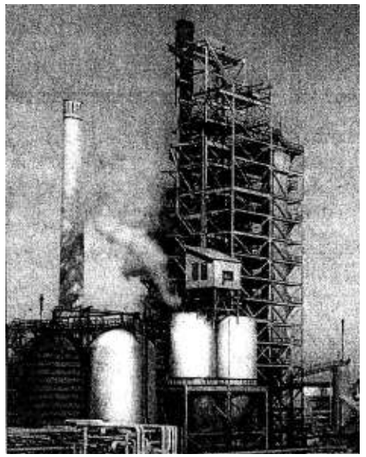
The World Leader in
Cyclone Design & Specialists
in Fluid Bed Applications

CECO
ENVIRONMENTAL

Emtrol-Buell

We Are Emtrol-Buell
A CECO Environmental Brand

History



First Commercial FCC Unit (1942), Baton Rouge, LA USA

Since its founding in 1934, Buell has been actively engaged in the study and development of cyclone technology. In the 1940's, Buell pioneered the cyclone design that was successfully used in the first commercial FCC unit located in Louisiana, USA. In the 1960's, Buell's continued development efforts in cyclone technology led to the successful entry in the newly developing petrochemical industry with cyclones that resulted in increased efficiency.

In 1973, Emtrol was established by a group of former Buell employees who successfully grew their business to also become a major equipment supplier to the same market. Throughout the next 40 years, both Buell and Emtrol continued to develop their engineering expertise including numerous patents for cyclone separation technology. As a result of their focus on proven performance, quality and reliability of cyclone equipment, that had become expected by the customer base, Buell and Emtrol became the two major suppliers of FCC cyclones and related equipment to global petroleum refining and petrochemical industries.

In 2014, CECO Environmental (parent company of Buell) purchased Emtrol and integrated the two industry leaders to form Emtrol-Buell Technologies. The merger created the largest, most experienced global market leader in cyclone technology servicing fluid bed applications and third stage separators for the petroleum refining and petrochemical industries. With corporate headquarters in New York USA, combined with regional offices in Pennsylvania USA and the United Kingdom, Emtrol-Buell is well positioned to support both current and future requirements of its global customer base.

Experience

We are the world leader in cyclone design, FCC cyclones and specialists in fluid bed applications. Our staff has over 350 years of engineering, design and technical service expertise.

We have many chemical and petrochemical applications as well, including Acrylonitrile (ACN or AN, Catoxide, Fluid™ and Flexi™ Coking (trademarks of ExxonMobil, Low Density Polypropylene (LDPP, Polypropylene, Oxy Hydrochlorination (OHCL, Polysilicon Hydrochlorination, SZORB™ (trademark of ConocoPhillips and Vinyl Chloride Monomer (VCM) just to name a few.

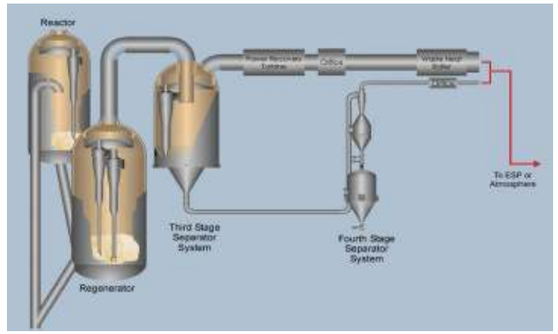
Our clientele encompasses many of the prominent oil refiners worldwide, and we have the largest installed-base of any FCC cyclone supplier in the world with over 3700 cyclones supplied since 2000.

Our sound technical support, coupled with superb engineering and design support, has rendered us a favorite among these major corporations. The continued interest and repetitive business of the established clients, and their affiliates, promote our expertise in this field – there can be no greater endorsement for our superior design than that!

FCC Cyclone Equipment

We have supplied the following FCC equipment in accordance with Refinery, EPC and Process Licensor specifications:

- Reactor Cyclone Systems
- Regenerator Cyclone Systems
- Third Stage Separator Systems
- Fourth Stage Separator Systems, UnderflowPiping, Critical Flow Orifices
- Catalyst Hopper Cyclones
- Cyclone Replacement Parts
- Cyclone Valves
- Vessel Heads and Entire Vessels
- Risers, Steam Rings, Air Grids, Spent Catalyst Distributors



Typical Refinery FCC Process and Equipment

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FCC Cyclone Design

We have incorporated many new features into our cyclones to enhance the separation efficiency, accommodate increased catalyst loading and minimize wear on internal surfaces of the cyclone equipment. Some new design features focus on:

- Aspect ratio of the cyclone inlet
- Limitations on flux rates
- Cyclone inlet to outlet criteria

Cyclone Hanger Support Systems

All internal Regenerator cyclone systems must be supported in a manner that accommodates the differential thermal expansion that exists between the relatively cold vessel, which supports all vessel internals, and the cyclone system, which is exposed to a much higher temperature.

The Emtrol-Buell Patented Beam Hanger System utilizes an array of horizontally oriented beams, which extend radially from the plenum skirt toward the vessel head, from which both the first and second stage cyclones are supported.

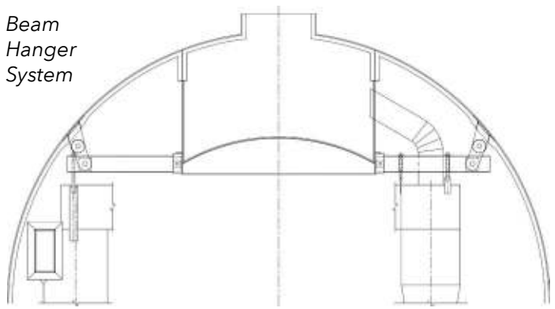
The inboard ends of the beams are supported by the plenum skirt and outboard ends are supported by links attached to lugs welded to the vessels head. By locating the linkage supporting the cyclones toward the outboard end of the beams, the majority of the load from the cyclones is supported from the vessel lug, hence minimizing the load into the plenum.

Other 'construction details' related features include:

- New crossover duct design
- Minimized use of edge bars in refractory linings throughout cyclone assembly

We have also developed a dust hopper and lined dipleg stub design that enhances the catalyst discharge from the cyclones and mitigates the effects of erosion.

Beam Hanger System



The pin-connected links located on the outboard end of the beams are free to move when the beams increase or decrease in length due to thermal expansion/contraction. Hence, the beam remains virtually **horizontal** at all times, and is growing in unison with the cyclones it is supporting.

Furthermore, the cyclones are directly supported from the beam system by hanger straps/rods which remain **vertical** throughout the operating cycles, thereby eliminating horizontal force components on the cyclones. The system remains in expansion balance through the full range of operating temperatures, including over-temperature excursions, thereby markedly reducing the potential for severe damage in the event of such excursions.

Third Stage Separator (TSS) Systems

Many of our contracts have been for TSS System installations, of which about half are utilized solely for final particulate removal to meet air pollution control regulations. The balance of these units are located upstream of Power Recovery Turbines (PRT) and provide protection for the turbines, as well as reduction of catalyst emissions to the atmosphere.

All the installations upstream of a PRT are designed to handle the flue gas at the elevated Regenerator temperature and pressure, and are contained in their own pressure vessels. The units used solely for pollution control have been installed at various locations in the flue gas line, resulting in a variety of configurations, metallurgy and constructions to meet specific refinery needs.

Third Stage Separator (TSS) Cutaway

Fourth Stage Separator (FSS) Systems & Catalyst Hoppers

FSS cyclones are installed in the underflow from the TSS and are used to collect solids that have already been separated in the TSS. Solids separated in the TSS are transported to the FSS System using a small percentage of the flue gas as a transport medium for the catalyst, which is controlled by an orifice normally located downstream of the FSS cyclone.

There are many different configurations for the underflow and FSS System, which must also be designed to accommodate unloading of the solids from the fines collection hopper. Our FSS Systems are typically designed and fabricated to pressure vessel standards, are supported by the fines hopper vessel, and have been supplied for many TSS Systems.

Our Catalyst Hopper Cyclones are easily adaptable to a variety of applications, including loading and/or unloading of Fresh and Spent Catalyst, or as auxiliary hoppers for special additives. These cyclones are typically designed to minimize catalyst loss to the atmosphere in the vent from the hopper during loading and/or unloading operations.

Engineering Services

Since our inception, we have provided engineering services through the design of equipment for the refinery and petrochemical industries. In recent years, these industries have increased their requirements for more detailed evaluation to assure proper application and adequacy of equipment. We have met this challenge through the utilization and development of advanced technical software packages to meet or exceed expectations.

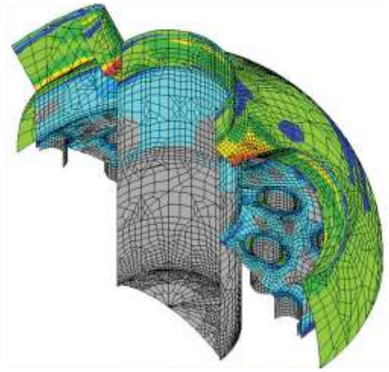
Emtrol-Buell's engineering services include a full range of design capabilities, including design of pressure vessels, piping and structural analysis. We reference the following codes and standards for which we are most familiar, but note that we can also incorporate individual specifications when requested:

- ASME Boiler and Pressure Vessel Code, Section VIII, Divisions 1 and 2
- ASME B31.3, Process Piping Code
- ASTM – American Society for Testing Materials (Materials)
- AISC – American Institute of Steel Construction (Structures)
- UBC – Uniform Building Code (Wind and Seismic)
- ANSI/ASCE – American Society of Civil Engineers (Wind and Seismic)
- WRC – Welding Research Council (Attachment Load Stresses)
- Roark's Formulas for Stress and Strain (Component Stresses)

In addition, we offer inspection services during installation or regular maintenance shutdowns from our three global locations. In 2015, we introduced 'Service Pac', a new bi-annual process review and annual mechanical review, which offers a new, long-term approach for support to ensure that our client's FCC is operating at its maximum level of performance.

Finite Element Analysis (FEA)

Since 1989, we have been supplying comprehensive 2D FEA models for the design of plenum chambers. In order to accommodate non-symmetric and/or non-uniform loadings, we also offer 3D modeling and analysis that is conducted in-house to ensure timely response to design changes. 3D modeling permits detailed design for unique loading conditions and depicts the effect of the non-symmetric loading. Although primarily used for analysis of the primary membrane and bending stresses due to cyclone loadings and pressure, 3D FEA models can also incorporate the secondary thermal stresses produced by the thermal gradient in the plenum skirt.



Through 2015, we have provided over 400 FEA models, many of which have been for major petroleum refining companies, and have included:

- 2D axisymmetric modeling for thermally induced stress
- 3D shell element modeling for pressure vessels
- 3D brick element models for complicated geometry

Installing Refractory Lining

Fabrication

Emtrol-Buell uses quality subcontractors for the manufacture of our equipment. Our subcontractors have personnel dedicated to specific tasks, including hexmesh installation, assembly and fit-up, welding and refractory installation.

The product of our long-term affiliation with our subcontractors is their extensive experience in the fabrication and refractory lining of this specialized equipment for FCC applications. Together with Emtrol-Buell, our subcontractors in North America, Europe and Asia have developed industry-leading methods to manufacture superior quality equipment, which has become synonymous with our name.

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Installing Plenum into Vessel Head

Heat Curing and Post Weld Heat Treating of Refractory Lined Cyclones

World Wide FCC Installations

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