CREL INDUSTRIAL PARTICIPATION PLAN

Chemical Reaction Engineering Laboratory (CREL) at Washington University is a unique academic organization that pools industrial and governmental resources for needed long-term fundamental research in reaction engineering, conducts such fundamental research and transfers the results to industrial practice. CREL provides broad and in depth reaction engineering education and training both to students and industrial practitioners. CREL makes it possible for industrial sponsors to take a long term view and participate in the development of new ideas, methods and techniques. **By pooling industrial resources together with governmental funding CREL offers unique and attractive opportunities for leveraging of company and government resources. Both systematic long term studies via students' theses and contract work for sponsors are pursued.**

CREL's objectives are:

1. To advance the reaction engineering methodology in scale-up, design and trouble shooting of multiphase reactors through basic research of the key phenomena and achieve environmentally acceptable processes. Areas of interest to CREL's industrial sponsors are given special consideration.
2. To educate students and produce new reaction engineers.
3. To develop and verify reliable experimental techniques for measurement of various fluid dynamic and kinetic parameters in multiphase reactors and bioreactors such as velocity, holdup distribution, turbulence, bubble sizes, heat transfer, kinetics, catalyst deactivation, and characterization, etc.
4. To utilize reliable measured data in verification of kinetic models, reactor scale models and Computational Fluid Dynamic (CFD) models and in integrating these models for reliable design and scale-up of multiphase reactor systems.
5. To implement and modify reaction engineering methodology for new emerging technologies that include bioprocessing technology in order to speed up the commercialization of bench scale data.
6. To utilize state-of-the-art expert systems and control theory and advance their applications in reaction engineering.
7. To develop and maintain close ties with industry.
8. To transfer academic research to industrial practice by bridging the gap between academic research and industrial applications.
9. To provide unique educational and contract services in all of the above areas to our industrial sponsors.
10. To offer access to sponsors to the unique experimental facilities for studies of multiphase systems (e.g. CARPT-CT, optical probe, heat transfer probe, mass transfer probe, tracer techniques, gas dynamics technique, cold and hot multiphase reactor set-ups for process evaluation, catalyst testing and kinetic studies, etc.) and to provide assistance in utilizing CREL developed models/simulations with the multiphase flow model simulators.
11. To offer training and short courses to our sponsors.
12. To be of service to industry and community.

In order to accomplish the above objectives CREL relies on industrial partnerships described in Figure 1.

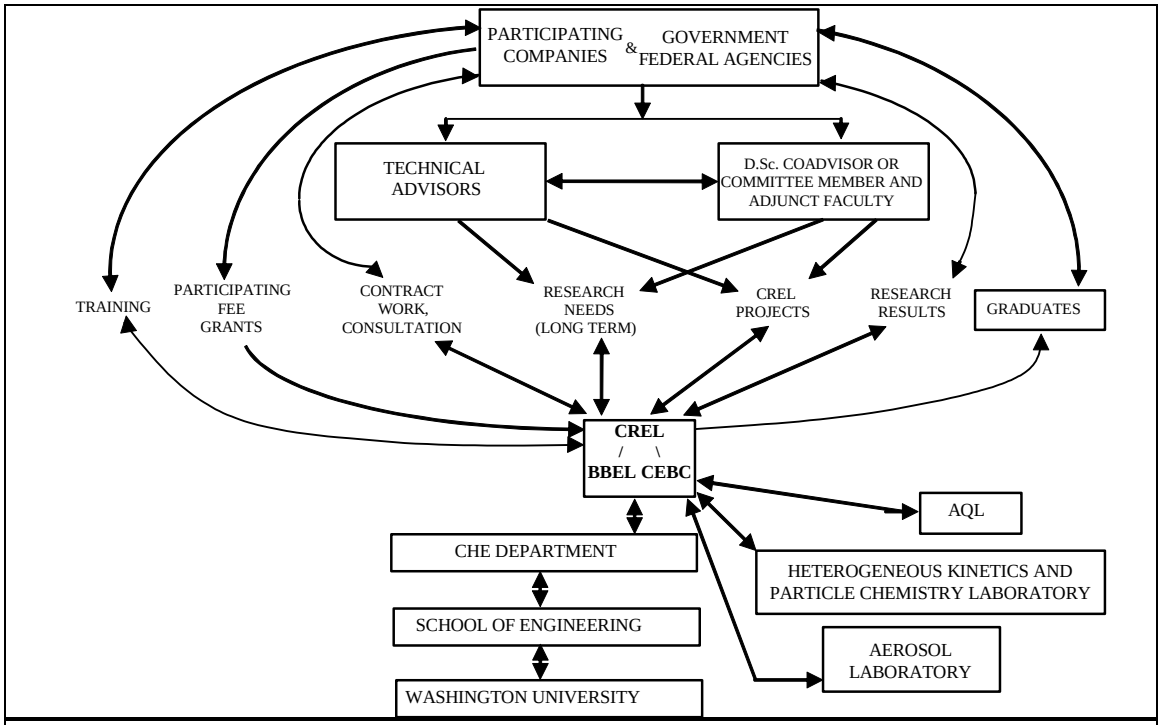

FIGURE 1: CREL Modus Operandi

Industrial organizations can become members of the CREL industrial consortium by one of the following two means: regular or special membership.

Regular members pay the annual participating fee of **$20,000/year** for which they are invoiced in the December-January time frame. Becoming a regular CREL sponsor entitles the company to appoint one or more technical advisors, as appropriate, for the following interaction avenues with CREL:

i) Technical advisors to CREL review CREL's activities, attend its annual meeting and distribute its annual technical research results and reports to their colleagues. They generate ideas for needed long term research projects and pass this on to the CREL director. CREL doctoral thesis projects are selected from this pool of ideas. The technical advisor from the company, whose idea was selected for thesis work, becomes the student's thesis co-advisor and adjunct faculty member. The CREL projects supported by the fees of regular CREL members and by the federal agencies produce research results which are shared immediately with all the sponsors and then later on via theses and publications with the general public. Participating companies have the option of having students execute part of their research on their premises and certainly have the best opportunity to hire these individuals upon completion of their degrees.

ii) CREL does provide consulting and contract work only for participating companies. The nature and results of this work are kept proprietary, and the reports are only given to the sponsoring company. It is the task of technical advisors to identify areas

in which CREL can contribute to their company via contract work. CREL's unique experimental facilities are accessible only to participating companies.

iii) CREL also provides education and training in various aspects of reaction engineering for industrial sponsors, either at Washington University or on companies' premises.

iv) CREL is always prepared to undertake joint research projects with industrial sponsors with or without federal funding.

Special members of CREL pay a **varying annual participating fee (more than $20,000)**, depending on the scope of work, with three year guaranteed minimum. Special membership, in addition to the interaction avenues described in i) through iv) above, guarantees a Doctoral (or Master) thesis on the topic of direct interest to the sponsor with some selected results to be protected by proprietary agreements. The representative of the special member company is appointed as graduate student co-advisor or graduate student committee member and adjunct faculty member. Research can be conducted at CREL or at company premises.

Both regular and special members have the rights and privileges of joining mini consortia developed for in-depth study of special topics of interest to some companies. The fees for the consortia vary and are determined in consultation with company representatives and depend on the scope and magnitude of the project and work to be done.

Since CREL's major products are research results, technical and scientific consultations, recommendations and graduates, and industry is the main customer for these products (Figure 2), **the CREL industrial participation plan provides a unique opportunity for industry to affect the products it is about to receive.**

Benefits to participating companies are many and are not limited to:

- leveraging of industrial resources by having CREL execute needed research with government funding,
- some free consultation on CREL premises,
- providing input to CREL long term research,
- early review of CREL research results and graduates,
- opportunity to gain rights to CREL results, expertise and discoveries,
- having an input for selection for CREL future thesis projects,
- opportunity to co-advise graduate students and serve on graduate theses committees as adjunct faculty,
- opportunity to subcontract work to proven university personnel,
- having CREL personnel available for short and long term contract work and consultation,
- opportunity to do joint research with CREL,
- having access to unique facilities,
- educational and training courses provided by CREL,
- access and recruitment of high quality graduates.

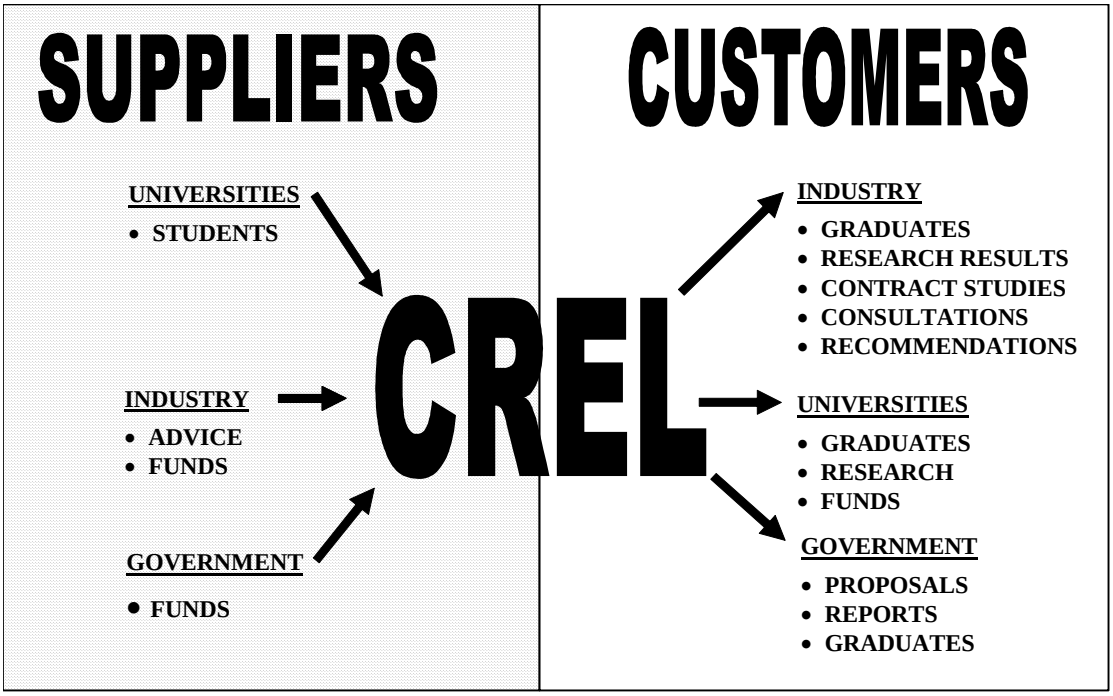

FIGURE 2: Customer-supplier Relationship for a Typical University Laboratory like CREL.