

PHASE VI • ADVANCED CENTRIFUGAL PUMP and COMPRESSOR CONSORTIUM for
DIFFUSER & VOLUTE DESIGN
FREQUENTLY ASKED QUESTIONS

1. How will information from the prior five Consortia phases be covered?

- The information in the Technical Memoranda (TM's) was reviewed in detail for the initial round of sponsors during a 2-day meeting in November 2013 at the Concepts NREC headquarters in Vermont. Notes from that meeting will be sent out to new sponsors and a webinar-based session will be offered periodically to allow new sponsors to review the material with Concepts NREC and ask questions.

2. What is the specific speed (and or flow coefficient) of the impeller that will be tested in Phase VI? What specific speed impellers will be tested in phase VII?

- We have three stages that we use: An industrial stage with $N_s = 55$, a common medium pr stage with $N_s = 85$, and a high $N_s = 110$ stage. These stages are for $pr = 1.8, 3.5$ and 4.5 ; two are transonic. Other stages may be added, as planned in the program.
- The low specific speed stage is available for either gas or water testing.
- Each of these stages is important to all participants as they are essential for developing correlations that are correct across a span of parameters with proper asymptotes at each end of the data range; serious errors result when a narrow range of investigation is employed.
- We anticipate using all stages within the first two programs; participant input will be important for the specific choices. Custom testing can also be arranged via other contracts.

3. What range of R_3/R_2 will be examined for the vaned diffuser cases (Diff. inlet radius/impeller exit radius)?

- Perhaps as low as 1.01 and as high as 1.15.
- Past experience points in the direction of conducting most work over the proposed three phases in the range of $R_4/R_3 = 1.15$ to 1.3.

4. What is the nominal size of the impeller? (R2, B2)

- Nominal sizes range from about 3 to 6 inches.
- This size has been demonstrated to give very good diffuser performance with repeatability.
- Concepts NREC has the capability and experience to use larger size impellers and this may be done in the last phase; however, the costs rise quickly and the amount of data and builds reduces proportionately.

5. What range of machine Mach numbers will be evaluated?

- We haven't booked this parameter specifically but the range is wide.
- The impellers have inducers that run from modest subsonic inlet relative Mach numbers to fully transonic, reaching local relative Mach numbers of about 1.2 – 1.3.
- The impeller exit Mach numbers likewise pass the transonic regime, but all vaned diffusers are designed so that the leading edge Mach numbers, absolute frame, are subsonic in order to permit good operating range (see examples published).

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6. The proposal states that Phase 6 will focus on strategies to approach or exceed 80% recovery and that $C_p=0.75$ has been achieved previously. What was the configuration with which you achieved $C_p=0.75$?

- $C_p = 0.75$ was achieved on several different configurations with a 4 degree setting angle as a variant of our best airfoil diffuser.
- This result showed that higher recovery is possible, but the design methods to achieve it routinely are not yet fully evolved.
- This work was done with our highest specific speed impeller at full operating speed.

7. Is this work relevant to turbochargers?

- Yes, by all means! Only the lowest specific speed impeller is not directly related to turbocharging, but even that case helps anchor important characteristics for the higher N_s stages which are quite pertinent to turbocharging.
- A significant number of diffusers have been designed for turbochargers based on the prior consortium work.
- Most of the work in the prior projects is applicable to turbocharging and nearly all of the future work will be especially relevant.

8. For vaneless diffuser tests, what parameters will be studied?

- Several tests are initially planned but are important so as to learn more about the coupling of rotor/diffuser as inlet curvatures change.
- We will use existing hardware from past tests and instrument heavily to find more details of these coupling effects.
- Voting by members will control the window for other tests in this area; time will tell.
- More vaneless data is available in a companion project and will be brought in if helpful.

9. Regarding the updated models in COMPAL, will these be exclusively available to the consortium participants? Will they be available to other software customers, if so, after what period of time?

- The models will be exclusive to the participants for the 7 year confidentiality period. As new models are added, the period starts again for those new additions. So the last version will only be available in the 14th year after project start to non-sponsors and then only if release is given.
- Specialized models, using client data, can also be built using supplementary contracts.

10. Patent Rights

- Patent rights (licenses) will be issued from time to time as new patents are issued. One is in process at this time and will be discussed in memos in a matter of some weeks/months after starting the program.
- Licenses will be issued on a non-exclusive, royalty free, worldwide basis, contingent on a sponsor finishing and funding the specific phase of work and being current in all prior payments. These licenses will be drafted by Concepts NREC and its IP law firm so as to protect all involved.
- The license is only for the sponsoring division of the company involved (*firm* policy since 1975). A license can be sold with the licensed division if it is sold, or retained in another division but must be formally transferred via Concepts NREC; however, the license cannot be split. Several companies are electing Enterprise Wide Licenses to include all divisions of the company, now and in perpetuity.
- We will patent in a number of countries but possibly not all the countries desired by each participant. We will let participants know what countries we are filing in and if additional countries are needed we will work with the specific company(s) to resolve this issue. There will be no charges or additional fees for these licenses unless sponsors desire a very wide range of countries to be covered by the patents.

11. What kind of blading will be used for the impellers?

- Currently, all cases are ruled element blading.
- We can easily introduce an advanced stage into the Phase 7 or 8 work scope if this is of interest to the Consortium. Simply a matter of ballot voting.

12. What patents have been issued before?

- US patent number 5,368,440 was issued for the prior work
- It served as protection for all users employing LSA diffusers from the past studies

13. How are the new three phases of the work different than the last five?

- The past five programs laid out design methods and performance levels for a variety of diffuser types, including introduction of the LSA diffuser to many companies.
- Various configurations have been employed in new machines as a consequence.
- Phases VI – VIII are focusing on how to get a wide range diffuser to possibly break the 80% recovery goal and the supporting technology to do this and design accordingly.
- To meet this end, fundamental questions as to rotor/diffuser coupling must be answered and these are captured in the project plan.

14. Will you use cover bleed on any of the compressors to push for wide range?

- Yes, we have used cover bleed in the past programs and have done several good commercial designs since then.
- At client's option, by the ballot, we can include cover bleed again.

15. Will you be testing really new diffusers?

- YES. This is a fundamental goal of the work.
- One new design will be in Phase VI and multiple new designs will be included in phase VII and VIII.

16. Do we need to participate in all five prior consortium phases?

- Yes, we will be drawing on information from all prior phases.
- One Exception: Phases IV and V are not too important for some pump companies and may be omitted for such companies; however, this does not apply to high pressure pump design companies such as boiler feed pumps, and certain aerospace and military applications. To be decided on a case by case basis.

17. SBIR projects were referred to in the WEBINARs from January; will any of this data be included?

- Yes, we will introduce such information wherever it is helpful.

18. Also mentioned were some companion consortia programs that are relevant but not specifically focusing on diffusers and not part of the 5 program series; will they be used?

- Yes, we will introduce such information wherever it is helpful.
- We will also make such studies available to diffuser consortium members at a strong discount, should full access to other program data be desired for any purpose.

19. Will structural analysis be included?

- Yes full modal calculations will be made for both the impeller and the diffuser and interference diagrams will be presented.
- Methodology for such analysis will be taught.

20. Will manufacturing be included?

- Absolutely. Low cost methods of making the new diffusers will be presented.
- Indeed, a new generation of flank milling has already been used for the baseline compressor.