Joint Industry Project
PRV Stability – Round II
Request for Proposal

PRV Stability

Research Program

RFP For Stage 1

Revision	Description	Date
A	Strawman document to potential Participants	
B	Strawman Issued For 4/25/2013 Meeting in Las Vegas	Jan 2013
C	Draft RFP Issued for review Incorporating Meeting Notes from 4/25/13	May 2013
D	Draft RFP Issued for Participant Review	June 2013

Request for Proposal

June, 2013 (Draft D)

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1 EXECUTIVE SUMMARY

1.1 Summary

The overall goal of this research project is to create a simple model, set of equations, or other tool that can be used by typical plant engineers to predict stability (e.g. flutter or chatter) for most of the PRV installations (from here on called "the model"). The model will need to be validated through literature and experimental results. Any limits or bounds that limit the model's validity will need to be identified and documented. The model should accurately predict stability within a defined confidence level and not predict stability for installations that are unstable. This research project will be broken into Stages and this RFP is only for the work described in Stage 1. Information on the remaining Stages is provided for reference.

1.2 Overall Project Scope and Execution Process

The overall scope of the research project is to provide a method that has been validated by test data and can be used by typical engineers. This project will be broken down into Stages with funding Stages, research contracts, and participation commitments renewed at each Stage.

Stage 1: Develop a simple model based on available literature and develop recommendations on test procedures/matrices

Stage 2: Execute proposed testing and update model as needed and develop recommendations on test procedures/matrices

Stage 3: Review consequence data for chatter failure mechanisms to provide advice to avoid failures

Stage 4: Provide recommendations for corrective or mitigating actions

1.3 Stage 1 Goals and Objectives

The primary goals for this Stage of the PRV Stability Research Program are three-fold:

1. Within a year of starting the project, create a simple model that can predict stability (e.g. flutter or chatter) for most of the PRV installations and has the limits well understood and documented. The model would accurately predict stability within a defined confidence level and not edict stability for installations that are unstable. The model should

predict whether PRV installations that are otherwise stable may be subject to temporary instability throughout the opening and closure of the valve disk.

2. Develop a practical tool, chart, data, and/or equations that can be used by typical engineers to determine the adequacy of relief device stability.
3. Recommend how the project should proceed and what would be required to proceed with model refinement (e.g. more testing, complex modeling).

1.4 Project Scope - Stage 1

To ensure that research and testing funds are directed to appropriate testing procedures, the purpose of Stage 1 is to develop a model based on existing literature and to propose a testing program/matrix to increase the usefulness of the model and increase the confidence in the results. Stage 1 has the following stages:

1.4.1 Stage 1.1 – Literature Update

This stage is expected to help avoid expending research effort that duplicates existing work and knowledge. The following objectives are identified for this stage:

- Update the literature and incident databases search results that were obtained during the PERF-99-05 Project
- Identify currently available stability models in use for analyzing PRV instability
- Identify and consolidate all available test data to use to validate models

At the end of this stage, the Project Execution Coordinator and the Lead Researcher from the contract research organization will prepare a report of the results and review the deliverables in person at a meeting that is open to representatives of the participants. The participants will review the work performed in this stage and vote on whether or not to continue to Stage 1.2.

1.4.2 Stage 1.2 – Consolidate and Summarize the Available Data

The following objectives are identified for this stage:

- List and compile data from the existing data sources to be used as validation of the simplified model.
- Consolidate and summarize the available data and list any concerns or limitations of the data based on the works published.
- List all relevant, publically available parameters.

At the end of this stage, the Project Execution Coordinator and the Lead Researcher from the contract research organization will prepare a report of the results and review the deliverables in person at a meeting that is open to representatives of the participants. The participants will review the work performed in this stage and vote on whether or not to continue to Stage 1.3.

1.4.3 Stage 1.3 – Create a Simplified Model

The contractor will create a model based on the available data. Interested parties will provide more detailed model results to help confirm the program's model. The scope of this model is to analyze chatter caused by the inlet piping installation. Chatter caused by other reasons (e.g. body bowl choking or outlet piping) are not included in the scope of this RFP. The following objectives are identified for this stage:

- The data that is used in the model is readily available or can be easily estimated.
- The model may be based on the existing models and/or existing data as collected in Stage 1.1, Literature Update.
- Properly validate the model to ensure that the goals listed above are met. For example, comparing the simple model against more complex models to determine the limits of the simplified model.
- Compare the model against the data collected in Stage 1.2
- Determine the confidence interval of the model to predict against available data. Failures to predict chatter need to be documented.
- The contractor will propose a path forward to gather additional data to further refine or validate the model.

At the end of this stage, the Project Execution Coordinator and the Lead Researcher from the contract research organization will prepare a report of the results and review the deliverables at a meeting that is open to representatives of the participants. The participants will review the work performed in this stage and vote on whether or not to continue to Stage 2. The participants will also vote on whether to authorize the contract researcher to write the final report or require that additional work be performed.

1.4.4 Stage 1.4 – Comprehensive Final Report

The objective is to document the findings of the entire research project.

The draft final report will be delivered to the listed representative of each participating company for review. Each company will have at least a month to review and approve the final report. The contract research organization will update the final report based on the comments received and reissue the final report to the listed representative of each participating company.

1.5 Vendor Selection and Project Initiation

Once bids are received from all interested parties, the proposals will be reviewed with the participants and consociates, and an overall contractor will be selected. At this point, a sponsoring organization will be chosen (i.e. PERF, CCPS, etc.). The project charter and contracts will be distributed to the participants and consociates, and if enough companies join the project, the contractor will be awarded the research contract. It is anticipated that this project will commence late 2013 or 2014.

2 REQUEST FOR PROPOSAL

2.1 Introduction

2.1.1 Background

The installation of relief device is covered by industry codes and standards.

2.1.1.1 Codes and Standards: Relevant Installation Guidance

Pressure relief valves (PRVs) are used throughout the hydrocarbon processing industry to minimize the risk of equipment failures from high pressures. PRVs are re-closable devices that are intended to re-seat once the pressure has dropped, thereby maintaining inventory and minimizing emissions. Pop-Action Pressure relief devices consist of a potentially un-damped or under-damped spring mass system that are subject to instability. Due to the potential for large forces from relief device instability and/or the potential loss of pressure relief capacity, good engineering practice is to install relief devices such that instability is minimized or nonexistent.

Existing installation guidance (as described in the next section) is based on simplified criteria to limit the inlet pressure losses. This is to maintain a margin between the assumed pressure relief valve re-seat pressure and the non-recoverable inlet pressure losses (in the piping between the equipment being protected and the pressure relief device). The previous PERF Study (detailed further in 4.3 Appendix C: PERF 1 Background) indicates that this guidance is insufficient and proposes that additional research be performed.

2.1.1.2 Codes and Standards: Relevant Installation Guidance

Several industry documents are available that specify details of design, sizing, installation, etc. of PRVs. One of these documents, API Recommended Practice 520 "Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries" Part II "Installation" states "excessive pressure loss due to friction at the inlet of a pressure relief valve will cause rapid opening of the valve. Chattering may result in lowered capacity and damage to the seating surfaces." It also specifies that "the inlet piping between the protected equipment and the inlet flange of the pressure relief valve should be designed so that the total pressure loss does not exceed 3% of the set pressure of the valve."

Similar limits can be found in ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Non-Mandatory Appendix M, Paragraph M-7 "Inlet Pressure Drop for High Lift, Top Guided Safety, Safety Relief, and Pilot Operated Pressure Relief Valves in Compressible Fluid Service," which states "the nominal pipe size of all piping, valves and fittings, and vessel components between a pressure vessel and its safety, safety relief or pilot operated pressure relief valves shall be at least as large as the nominal size of the device inlet and the flow characteristics of the upstream system shall be such that the cumulative total of all nonrecoverable inlet losses shall not exceed 3% of the valve set pressure."

2.2 Overall Project Scope and Execution Process

The overall scope of the research project is to provide a method that has been validated by test data and can be used by typical engineers. This project will be broken down into Stages with Sates for funding, research contracts, and participation commitments renewed at each Stage.

Stage 1: Develop a simple model based on available literature and develop recommendations on test procedures/matrices. O*nly the scope and work associated with this stage is included in this RFP.*

Stage 2: Execute proposed testing and update model as needed and develop recommendations on test procedures/matrices.

Stage 3: Review consequence data for chatter failure mechanisms to provide advice to avoid failures.

Stage 4: Provide recommendations for corrective or mitigating actions.

The anticipated scope and questions to be answered by this project are listed in Appendix D: Overall Project Objectives.

2.3 Stage 1 Goals and Objectives

The primary goals for Stage 1 of the PRV Stability Research Program are three-fold:

1. Within a year of starting the project, create a simple model that can predict stability (e.g. flutter or chatter) for most of the PRV installations and has the limits well understood and documented. The model would accurately predict stability within a defined confidence level and not predict stability for installations that are unstable. The model should predict whether PRV installations that are otherwise stable may be subject to temporary instability throughout the opening and closure of the valve disk . *The scope of this work is limited to API STD 526 conventional and bellows relief devices.*
2. Develop a practical tool, chart, data, and/or equations that can be used by typical engineers to determine the adequacy of relief device stability.

3. Provide recommendations on how the project should proceed and what would be required to proceed with model refinement (e.g. more testing, complex modeling).

2.4 Statement of Work - All Project Stages

With the exception of portions of the appendices and this section, this RFP only refers to Stage 1 of the project. This Section provides an overview of the entire project goals. The primary goals for the entire project for the PRV Stability Research Program are:

- *Stage 1* - Develop a model based on existing information in literature and perform the testing to validate that such a model accurately predicts chatter and does not identify installations that chatter as stable.
- *Future Stage* - Develop guidance on predicting whether PRV installations may be subject to instability throughout the opening and closure of the disk.
- *Future Stage* - Develop guidance on predicting consequences (e.g. damage to the piping, relief device, equipment) in the event of instability.
- *Future Stage* - Develop guidance for implementing mitigating or corrective actions that address potentially unstable PRV installations.

For all stages, the scope includes direct spring-operated pressure relief valves conforming to API Standard 526 having D to T orifices that discharge vapor, liquid, and/or two-phase services. An initial focus on vapor services is acceptable.

Two aspects of the overall program are anticipated: evaluation of stability and estimation of consequences. After the completion of Stage 1, these two aspects may be performed in parallel research tracks or even proposed upon separately.

Appendix D (§4.5) discusses the remaining project stages in general along with the questions the participants intend for the project to answer. These descriptions are based on the current knowledge of the subject and can change upon mutual agreement as the project progresses. "Researcher" refers to the lead organization executing the project as proposed and may consist of a group of organizations working together under the lead organization. The Researcher shall identify a technical lead responsible for communicating with the Sponsor Chair.

2.5 Stage 1 – Literature Update and Model Development

2.5.1 Stage 1.1 – Literature Update

2.5.1.1 General

Researcher will make a reasonable effort to identify and critically review information that has become available on the subject of PRV stability after this effort was made for the PERF-99-05 Project. The additional information should be critically evaluated for potential applicability to predict and/or describe factors influencing stability. The review should focus on, though not be limited to, those articles dealing with the effect of inlet line pressure losses on spring-loaded PRV stability in gas or incompressible liquid service.

Literature compiled during the PERF-99-05 Project as well as that is currently possessed by Participants will be made available at the start of this stage.

2.5.1.2 Goals and Objectives

This stage is expected to help avoid expending research effort that duplicates existing work and knowledge.

The following objectives are identified for this stage:

- Update the literature and incident databases search results that were obtained during the PERF-99-05 Project.
- Identify currently available stability models in use for analyzing PRV instability.
- Identify and consolidate all available test data to use to validate models.
- Particular attention should be given to the DIERS *Interim Research Report on Safety Relief Valve Stability and Piping Vibration Risk - 2003 - 2012*. Note that some of the authors may need to be contacted to further elaborate on their research and presentations.

2.5.1.3 Deliverables

The deliverables for this stage are:

- A copy of all material identified during the search.
- A written report on the critical review/evaluation of this information, including an executive summary of the relevant factors that influence PRV stability.

2.5.1.4 Stage Review with Participants

At the end of this stage, the Project Execution Coordinator and the Lead er from the contract research organization will prepare a report of the results and review the deliverables in person at a meeting that is open to representatives of the participants. The participants will review the work performed in this stage and vote on whether or not to continue to Stage 1.2.

2.5.2 Stage 1.2 – Consolidate and Summarize the Available Data

2.5.2.1 General

This step is to prepare a data set that can be used to benchmark the model created in Stage 1.3 (2.5.3). Several of the participants believe that the available data to review is more extensive than what was believed at the end of the PERF-1 study.

2.5.2.2 Goals and Objectives

The following objectives are identified for this stage:

- List and compile data from the existing data sources to be used as validation of the simplified model.
- Consolidate and summarize the available data and list any concerns or limitations of the data based on the works published.
- List all parameters relevant to the study that are publically available.

2.5.2.3 Deliverables

The deliverables for this stage are:

- A copy of all material identified and the datasets to be used for the next stage of this project stage.
- An analysis of the published data, methodological limitations, and other information that could limit the applicability or repeatability of the work for the purposes of this project. *Note that this may include a review of data where instability can be caused by body bowl choking.*
- An analysis of the areas where the data may be insufficient (e.g. lack of high pressure installations) to confirm the model. Alternatively, this may identify the initial limits of the model and lay the groundwork for the testing matrix (§2.5.3.3).
- A written report on the critical review/evaluation of this information, including an executive summary of the relevant studies/data that will be used to develop and proof test the model.

2.5.2.4 Stage Review with Participants

At the end of this stage, the Project Execution Coordinator and the Lead Researcher from the contract research organization will prepare a report of the results and review the deliverables in person at a meeting that is open to representatives of the participants. The participants will review the work performed in this stage and vote on whether or not to continue to Stage 1.3.

2.5.3 Stage 1.3 – Create a Simplified Model

2.5.3.1 General

Based on the research done by several of the participants, it is believed that the equations and/or systems of equations needed to create a simplified model are available (refer to §4.2). It is anticipated that this model will be a conglomeration of the existing models in literature. A further requirement of this stage is to prepare a testing matrix to further increase the confidence interval that the model is accurately predicting stability (and not predicting stability for unstable installations). This model is to analyze inlet piping and to exclude cases of chatter caused by body bowl choking or outlet piping. It is required to show that it is reasonable to assume that the outlet piping, if designed and installed per the manufacturers' requirements, will not appreciably contribute to relief device instability.

2.5.3.2 Goals and Objectives

The contractor will create a model based on the available data. Interested parties will provide more detailed model results to help confirm the program's model. The following objectives are identified for this stage:

- The data that is used in the model is readily available or can be easily estimated. Note that the DIERS *Interim Research Report on Safety Relief Valve Stability and Piping Vibration Risk - 2003 - 2012* contains means to estimate many of the critical parameters.
- The model may be based on the existing models and/or existing data as collected in Stage 1.1.
- Properly validate the model to ensure that the goals listed above are met. For example, comparing the simple model against more complex models to determine the limits of the simplified model.
- Compare the model against the data collected in Stage 1.2.
- Determine the confidence interval of the model to predict against available data. Failures to predict chatter need to be documented.

- Model should cover various types of mechanisms of excitation (e.g. acoustic resonance, pressure losses, blowdown effects).
- Delineate instability between chatter (metal-to-metal contact) and flutter (continuous cycling).
- The contractor will propose a path forward to gather additional data to further refine or validate the model.

2.5.3.3 Deliverables

The deliverables for this stage are:

- A working copy of the model in a spreadsheet or equivalent medium for the participants to use.
- Working copies of the data comparisons sets for the Participants to review and analyze.
- A written report including an executive summary of the relevant factors that influence PRV stability. The report will have sections that detail:
    - The parameters required for the model and how to find or estimate those parameters.
    - The basis or sources of the model (e.g. the EPRI Acoustic loss equations).
    - The weighing of certain equations for specific parameters (e.g. the source X is more accurate at low pressures and the Acoustic loss equations is more accurate at high pressures).
    - Details of the comparison of the model to the experimental results identified in Stage 1.2.
    - Limitations of the model and whether these limitations are due to insufficient data to validate the model or perceived inability of the model to accurately predict stability under the specified conditions.
    - Review of the model basis and underlying data that shows the various types of mechanisms of excitation (e.g. acoustic resonance, pressure losses, blowdown effects).
    - Review of the model basis and underlying data that shows the delineate instability between chatter and flutter.
    - Discussion of cases when the model failed to accurately predict chatter (e.g. models predicts stability when the experimental results chattered) and how to proceed or ensure that the results are conservative.
    - Proposed path forward, including testing matrices as needed to elucidate the effects of the different mechanisms of excitation that were not clearly available in the literature reviewed.

- Evaluate if a formal review of production relief device blowdown settings is required (see Jim Lay's presentation in the Diers interim report). Propose recommendations to ASME PRV Team / API STD 526 Task Force on minimum blowdown requirements / tolerances.

2.5.3.4 Stage Review with Participants

At the end of this stage, the Project Execution Coordinator and the Lead Researcher from the contract research organization will prepare a report of the results and review the deliverables at a meeting that is open to representatives of the participants. The participants will review the work performed in this stage and vote on whether or not to continue to Stage 2. The participants will also vote on whether to authorize the contract researcher to write the final report or require that additional work be performed.

2.5.4 Stage 1.4 – Comprehensive Stage 1 Final Report

2.5.4.1 General

This stage includes compiling the results from the other stages into a comprehensive final report.

2.5.4.2 Objectives

The objective is to document the findings of the entire research project. This final report will consist of consolidating the reports from all of Stage 1 for this project.

2.5.4.3 Deliverables

The deliverable for this stage is a final report and recommended revisions to API Standard 520 Part II that address PRV stability.

2.5.4.4 Stage Review with Participants

The draft final report will be delivered to the listed representative of each participating company for review. Each company will have at least a month to review and approve the final report. The contract research organization will update the final report based on the comments received and reissue the final report to the listed representative of each participating company.

2.6 Additional Project Information

2.6.1 Experimental Testing Facilities

TYCO International has offered the use of their testing facilities located in El Campo, TX. Other facilities have been identified, and Researchers will be expected to identify alternatives available to them.

2.6.2 Status Reporting

The Researcher's Technical Lead will be responsible for submitting monthly progress reports to the Sponsor Chair and providing the deliverables at the completion of each stage. The Sponsor Chair will be responsible for providing a monthly status report for the Participants. The Researcher's Technical Lead will be responsible for participating in the quarterly stewardship meetings and during the progress presentation, which is anticipated to occur twice a year in conjunction with the API Committee on Refining Equipment meetings.

2.6.3 Stage Decision Process

A phased decision process at the completion of each stage and sub-stage for this project is planned. At the end of each stage and sub-stage, the Participants will review the deliverables, ensure the deliverables accomplish the goals and objectives for that stage, consider modifications to the next stage, and make a decision regarding the path forward for the project. Outcomes of the Stage/Gate process may include decisions to proceed as planned, to proceed with modifications, to recycle, or to discontinue the project altogether. Decisions to proceed will be accompanied with an approval to disburse funding associated with that stage. Decisions to proceed with modifications may include an option to undertake additional requests-for-proposals to execute the modified scope of work. Decisions to recycle will be accompanied by a plan regarding whether or not additional funding will be provided, which may occur if the recycle is caused by a change in scope. Decisions to abandon the project altogether will be accompanied by a plan for closing out the project.

2.6.4 Project Bidding

The contractor should bid Stage 1 of this project as a lump-sum or on a time and materials reimbursable basis with a not-to-exceed upper limit. This is due to the funding mechanism for the work.

2.6.5 Researcher Selection

The project participants will select a sub-group to evaluate all proposals for this effort. This group will then present their recommendations to the overall group of participants for review. Unless a majority (over 50%) of the overall participant group has material concerns with the selection process of sub-group, the sub-groups selection will be chosen as a contractor. If the sub-group selection is rejected by a majority of the participants, the following will occur:

- If only two researchers bid for the work, the other researcher will be chosen.
- If more than two researchers bid, the research originally chosen by the selection committee will no longer be considered for this Stage of the Project and a new sub-group will be formed to evaluate the remaining bidders.

This process will be repeated until the winning researcher is found.

2.7 Proposal Information

2.7.1 Notification

Interested parties should submit a notification in the form of an application (Appendix A) to the Contract Coordinators, Dustin Smith (713.802.2647; dustin.smith@smithburgess.com) and Clark Shepard (703.846.3327; clark.d.shepard@exxonmobil.com), who is acting as the Setup Phase Sponsor Chair. The information received as part of the Notification will be reviewed by the Organizational Task Group, and a prequalification process will occur. During the prequalification process, a confidentiality agreement will be sent to the interested parties. Upon completion of the prequalification process, additional information will be sent to the interested parties.

Interested parties may consist of a coalition of researchers; however, a single point of contact regarding the proposal is required.

2.7.2 PERF 99-05 Reports

Once a confidentiality agreement has been executed with the interested parties, the following information will be made available for the purposes of creating the proposal:

- PERF 99-05 Phase 1 Report, "Stability of Pressure Relief Valves – A Review and Evaluation of Prior Work"
- PERF 99-05 Phase 2 Report, "Industry Survey"

- PERF 99-05 Phase 3 Report, “Stability Model and Testing Protocol”
- PERF 99-05 Phase 4 Report, “Pressure Relief Valves Testing Program”
- PERF 99-05 Phase 5 Report, “Mathematical Modeling and Analysis of Pressure Relief Valves Stability”

2.7.3 Requirements

Interested parties should submit a proposal that includes the following required information:

- Cost, resource, and schedule proposed to execute each portion of Stage 1 (documented in sections 2.5 through 2.6).
- Clear identification of work not included as part of the proposal but that should logically be included in Stage 1.
- Proposed milestones for each stage that are specific, measurable, and timed.
- Name and résumé of proposed Technical Lead and Principal Researcher(s).
- Names and history (e.g. CV's, Resumes) of the researchers that will work on the project.
- Provide projects that the Research organization has completed that are similar to this project (both in scope and topic).
- Provide a list of publications on similar topic by either the research organization or those of key personal on the project

The following information may be submitted as additional information:

- Proposed electronic data management / project collaboration tool
- Alternatives in execution for consideration by the Participants

2.7.4 Submittal

Interested parties should submit their proposals via email to the Contract Coordinators, Dustin Smith (713.802.2647; dustin.smith@smithburgess.com) and Clark Shepard (703.846.3327; clark.d.shepard@exxonmobil.com), on or before July 31, 2013.

It is the Participants’ intent to award contract(s) to the Researcher(s) who offer the "Best Value" to the Participants. Best Value will be determined by the Participants in their sole discretion. Any RFP responses will be comprehensively evaluated on multiple criteria, which may include but are not limited to the completeness of the response, technical appropriateness, price, coverage, schedule, references, experience, and risk.

3 ADDITIONAL INFORMATION

3.1 Program Organization

Information pertaining to the organization of the program can be found in the Project Charter- the current version of which available on request.

3.2 Questions

Any questions pertaining to this request for proposal or for information regarding sponsorship in the program, please contact Dustin Smith (713.802.2647; dustin.smith@smithburgess.com) or Clark Shepard (703.846.3327; clark.d.shepard@exxonmobil.com).

4 APPENDIX

Appendix A – Notification Form

Appendix B – List of PRV Stability Screening / Dynamic Models

Appendix C – PERF 1 Background

Appendix D – Overall Project Objectives

4.1 Appendix A – Notification Form

Primary Contact	
Name	
Number	
Email	
Mailing Address	
Organization(s) Information	
Legal Name	
Mailing Address	
Tax Handling Form	(select one) W-9 ǀ W-8 ǀ Certificate of Exemption

Please also submit the following with the notification for the purposes of prequalification:

- List of principal researchers along with their résumés / curricula vitae
- Description of similar types of research projects executed
- Details of familiarity with the subject matter

4.2 Appendix B: PRV Stability Screening / Dynamic Models

PERF 99-05 Project: PERF 99-05 PRV Stability Model

Chiyoda: Chiyoda PRV Stability Model

ioMosaic: SuperChems

Idaho National Laboratory: RELAP5

Kasai, K., "On the stability of a poppet valve with an elastic support", 1963

Green, W.L and G.D. Wood, "The stability of direct acting spring loaded relief valves taking into account the upstream conditions", 1972

Kondrat'eva, T.F., V.P. Isakov, and F.P. Petrova, "Dynamic stability of safety valves", 1978

Langerman, M.A., "An analytical model of a spring-loaded safety valve", 1982

Singh, A., "On the stability of a coupled safety valve – piping system", 1983

MacLeod, G., "Safety Valve Dynamic Instability: An analysis of chatter", 1985

Kastor, K.A., "Chatter instability of spring loaded pressure relief valves", 1986; "Relief valve chatter testing", 1992

Bostros, K.K., F.H. Dunn, and J.A. Hrycyk, "Riser-relief valve dynamic interactions", 1997

Fromann, O. and L. Friedel, "Analysis of safety valve chatter induced by pressure waves in gas flow", 1998

Cremers, J., L. Friedel, and B. Pallaks, "Validated sizing rule against chatter of relief valves", 1999

Smith, D., J. Burgess, and C. Powers, "Relief device inlet piping: Beyond the 3 percent rule", 2011

Interim Research Report on Safety Relief Valve Stability and Piping Vibration Risk - 2003 – 2012. DIERS, 2013

4.3 Appendix C: PERF 1 Background

4.3.1 PERF-99-05 Project (Round I)

The first joint industry project (PERF 99-05) for the PRV Stability Research Program was initiated to develop the relationships in the PRV installation that may affect the PRV stability, cast those relationships into a model that may allow for a prediction of PRV stability, and perform tests on a sample of installations to determine the feasibility of practical use of the model.

The API and the a consortium of API member companies commissioned a seven-phase joint industry project (PERF 99-05) to identify, from a more fundamental perspective, those factors that are important in influencing the unstable cycling or chatter of relief valves and to arrive at a more scientifically based criterion for selection and installation of valves which will ensure stable operation.

The seven phases of the PERF 99-05 Project were as following:

Phase I: Literature Search and Critical Review

Phase II: Industry Survey

Phase III: Engineering Model Design Planning

Phase IV: Experimental Program

Phase V: Mathematical Modeling

Phase VI: Engineering Tool Development

Phase VII: Comprehensive Final Report

In Phase I, approximately 65 references were identified which include material related directly or indirectly to the cyclic operation or stability of relief valves. There are additional sources cited within these references that were also pertinent and many of them were reviewed. The literature search and critical review phase has helped identify critical valve performance parameters that eventually were taken into account in developing an understanding of design and operation parameters that impact PRV instability.

In Phase II of the project, the industry was surveyed for incident that may be related to PRV instability problems.

At the end of Phase III, a mathematical model was developed to predict the opening disk lift versus time response of a pressure relief valve in vapor or gas service. The model predicts stability through simulating the time response of the disk, which can be monotonically stable, oscillatory stable, or oscillatory [illegible] The model accounts for the influence of the input parameters representing process conditions, valve physical parameters, and installation parameters, which were found to have a highly non-linear effect on the dynamics. Most of these parameters are readily available to the pressure relief valve designer, such as the process conditions and installation parameters; however, there are two parameters that are not considered to be readily available.

An experimental program was executed in Phase IV of the PERF 99-05 Project. The primary objective of the experimental program was to utilize the testing results to validate the mathematical Gas Valve Stability Model that has been developed in Phase III of the Project.

The experimental program was conducted using 18 conventional relief valves, representing three manufacturers, three valve sizes, and two set pressures. An initial valve characterization testing, with replication, was performed to obtain valve characteristics such as set pressure, blowdown, discharge coefficients, flowing capacity, and opening times, following the requirements of ASME Boiler and Pressure Vessel Code Section VIII and API Standard 526. The definition of opening time was not as straightforward as one may think at first glance, and further thought was given to the appropriate definition. After establishing the valve characteristics, several tests were run with varying inlet and outlet piping lengths as well as varying operational conditions, within the limitations of the testing facility. In the event a pressure relief valve failed to meet the fitness for service tests, it was removed from the testing scheme. Both the limitations of the testing facility and the failure of some relief valves led to gaps in the experimentation space; nonetheless, some duplication of the tests was performed for reproducibility.

It has been demonstrated that disk lift and other system transients that occur during PRV opening can be measured with excellent repeatability of results. Test procedures, instrumentation, and data reduction knowledge obtained from this test program will be applicable to future test projects that investigate dynamic response of PRVs and related systems.

In addition to the impact of valve installation parameter impact on stability, the experimental program has provided critical data on the impact of various operation parameters, such as depressuring rates, flow rate, and pressurization rates on PRV stability.

The Phase V of the PRV Stability Project was aimed to validate the applicability of the mathematical model for predicting the valve's initial disk lift as a function of time based on the completed testing program results.

The results indicate that while the model has promise, there are limitations on the practical use, including the following:

- The model shows strong dependence upon parameters that are not available from the valve manufacturer, such as the damping factor, which can depend upon local conditions (e.g. lubrication, contamination, alignment, history, etc.) as well as the geometry of the flow path around the disk (which varies with valve size and with manufacturer).
- There is no framework for the extrapolation of the parameters beyond the sample tests (in which the parameters were determined by fitting the experimental data).
- Some experimental runs found instability on closing as the equipment was being depressured, and the model was not designed to apply to relief valve performance at closing.

In addition, other models have been developed independently of that created during the PERF 99-05 Project. These models may provide additional insight into the prediction of PRV Stability.

4.3.2 PERF 99-05 Recommendations

At the conclusion of the PERF 99-05 Project, several recommendations were made for consideration in the next round. The recommendations were focused on improving the applicability of the developed mathematical model through better identification of key model parameters, expanding the pool of tested valves, and address some of the critical testing program observations. The PERF 99-05 Project recommendations were as following:

- The estimation of the "key" unknown parameters, the damping factor and the fluid deflection angle, presents the primary limitation on the application of the mathematical model. Nevertheless, the value of these parameters is paramount to predicting the dynamic response of the valve disk under any operating conditions. Unfortunately, the values of the parameters depend not only upon the design characteristics of the valve, but also (to some degree) upon the operating conditions (e.g. flow rate) and local environment (e.g. lubrication, contamination, alignment, history). It is expected that each valve will have a range of values for these parameters that reflects the stability characteristics of the valve; therefore, it is recommended that further tests be run on valves of different sizes from various manufactures over a range of set pressures (or flow rates) to enable a correlation of the values of the fluid deflection angle for these valves with set pressure (or flow rate). It is further recommended that special attention be given to a consistent lubrication procedure for the moving parts of the valve to ensure free dynamic operation, as well as that care be given to ensuring a clean environment for undamaged valves and consistent values of the damping factor. Variations of the values of the damping factor under these conditions should also be correlated with the valve operating pressure.

- The maximum tested pressure in the PERF 99-05 Project testing program was 250 psig. That leaves a great gap of pressure relief valves operating conditions that cannot be simply bridged through model extrapolation. It is therefore recommended that additional pressure relief valves be tested at higher set pressures. It is expected that the higher selected set pressures will be limited by the testing facility fluid flow capacity. Testing the same valve models and sizes that have been already tested is preferred, as it will provide a wider view of the performance of the same valve.
- It is also recommended to randomly select and test several pressure relief valve models not previously tested, and use the outcome of recommendations above to validate the model stability predictions.
- The mathematical model does not apply to the dynamic response at closing as this depends entirely on the nature of the pressure/energy source, which is beyond the scope of this model. However, from the current project observations, the stability at the closing can be linked to the system depressuring rate and the valve's blowdown setting. It is recommended that in any future testing plan the system depressuring rate and blowdown setting be considered as controlled variables. That will allow testing the valves at various ranges of depressuring rates and blowdown settings to understand their role in valve instability at closing. This is intimately linked to the strength of the pressure/energy source that drives the pressure in the vessel, and the rate at which this energy subsides after the valve is opened and closed (this scenario is not normally considered in relief system design, but must be considered if valve stability upon closing is to be predicted)

4.4 HIGH LEVEL PERF DATA SUMMARY

Waiting on Abdul (Failed to email him until 6/10)

4.5 Appendix D: Overall Project Objectives

The primary goals for all Stages of this project in the PRV Stability Research Program are three-fold:

- Develop guidance on predicting whether PRV installations may be subject to instability throughout the opening and closure of the disk
- Develop guidance on predicting consequences (e.g. damage to the installation) in the event of instability
- Develop guidance for implementing mitigating or corrective actions that address potentially instable PRV installations

The scope includes direct spring-operated pressure relief valves conforming to API Standard 526 having D to T orifices that discharge vapor, liquid, and/or two-phase services. An initial focus on vapor services is acceptable.

Two aspects of the program are anticipated: evaluation of stability and estimation of consequences. These two aspects may be performed in parallel research tracks or even proposed upon separately.

The following sections describe each stage of the research project in greater detail. The descriptions are based on the current knowledge of the subject and may change upon mutual agreement as the project progresses. "Researcher" refers to the lead organization executing the project as proposed, and may consist of a group of organizations working together under the lead organization. The Researcher shall identify a technical lead responsible for communicating with the Sponsor Chair.

Several outstanding questions have been identified that are intended to be answered by the Overall Project. Some of these questions may be answered as part of Stage 1. Others will be answered in future work.

- While chatter is recognized as unstable behavior that is damaging to the valve, are there frequencies and/or amplitudes of oscillating behavior (with or without contact of the disk seat) that are unlikely to result in damage? In other words, what constitutes damaging flutter (non-contacting oscillation), damaging cycling (contacting oscillation of much lower frequency than chatter), and non-damaging oscillations?
- Is it possible to develop a screening heuristic/map that qualifies whether or not a pressure relief valve is likely to behave in an unstable manner causing damage to the valve for a given installation? In other words, are there boundary conditions that can be established for the purposes of

screening, despite the actual valve behavior being non-linear in response to various aspects of the system?

- Is it probable that the margin (i.e. difference) between the blowdown setting and the irreversible pressure losses in the inlet line to be one of potentially many boundary conditions that can be applied to the screening? If so, what is an appropriate margin, and is there any difference in this margin based on the type of pressure relief valve (i.e., conventional, balanced, or pilot-operated)?
- Is there sufficient similarity among valve sizes for a particular manufacturer and model, as well as among valve models for different manufacturers, to allow for a generalized screening heurtistic/map? To allow for the application of the dynamic model?
- Can a reasonable range of values for the damping factor and deflection angle be established to give best fit and/or conservative estimates in the application of the PERF 99-05 Project dynamic stability model? Perhaps as a function of set pressure, flow rate, or other variables?
- Based on the PERF 99-05 Project sensitivity analysis, the stability of the valve response was found to be "most sensitive to the blowdown setting." Given the sensitivity and the range of blowdown values found in the PERF 99-05 Project, does there need to be a tighter range placed on 'acceptable' blowdown values on production pressure relief valves?
- What attributes of a particular installation are needed in order to determine whether the pressure relief valve may behave in an unstable fashion causing damage to the valve while closing? Can the PERF 99-05 Project dynamic stability model be updated to incorporate these effects?
- What effect does the backpressure and/or body bowl choking on a pressure relief valve have on its stability? How do different relieving phases affect the stability of and/or damage to the valve?
- Is the hard stop at maximum lift (the 'restitution' as indicated by Singh 1983) an important parameter that needs to be incorporated into the PERF 99-05 Project dynamic stability model?
- How should API RP 520 Part 2 be modified to reflect general guidance to minimize the likelihood of unstable PRV operation resulting in damage to the valve?