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Development of design calculation templates for safety valve products as per ASME section III standards

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Abstract. Safety valve manufacturers have to perform repeated design calculations during product development, design verification, and manufacturing related activities. It results in increased calculation time, and possibility of errors [1,4]. This study presents the development of a template for safety valve products based on ASME Section III requirements [5]. The framework involves ASME Section III, ASME Section II Part D, ASME B16.34, ASME 36.10 & API 526 into a unified engineering calculation environment [5,9]. The developed system automates allowable stress determination, pipe dimensions, pressure rating verification & minimum wall thickness of valve body. A representative case study was conducted to validate the framework. Results obtained from the automated framework showed complete agreement with manually verified calculations. The main difference was time taken to complete the calculation, manual calculations took 45 minutes and for automated calculations it took 10 minutes. The proposed framework supports design standardization, improves productivity and enhances manufacturing readiness of safety valve products.

1 Introduction

Pressure safety valves are critical components used in pressure containing systems to protect equipment and personal against overpressure conditions. They are widely utilized in power generation, oil & gas, chemical processing and industrial manufacturing applications where pressure safety is important [1,2].

Development of safety valve products involves numerous engineering calculations associated with material selection, allowable stress, pipe dimensions, pressure rating verification, and valve body thickness calculations. These activities must satisfy the rules stated in multiple engineering standards such as ASME Section III, ASME Section II Part D, ASME B16.34, ASME 36.10 & API 526 [5,9].

Conventionally in industry, engineers perform these calculations manually by consulting various standards and reference data tables. This approach increases engineering efforts, extends products development time, and introduces the possibility of error in calculations [2,4].

The study focuses on design automation and standardization of safety valve engineering calculations to improve product development efficiency and manufacturing readiness. The

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proposed framework automates calculations by integrating codal requirements and engineering calculations withing one single platform [4].

2 Literature Review

Previous studies are based upon safety valve sizing methodologies, pressure relief systems, and valve performance optimization. Darby and Aldeeb [1] discussed proper sizing and selection of pressure relief valves. Crowl and Louvar [2] studied design principles of pressure relief systems used in process industries. Schmidt and Friedel [3] investigated design and optimization of safety valve under varying pressure conditions. More studies have examined valve performance through experiments and numerical simulations [11,12].

Excel based engineering automation has also been used as an effective method for reducing repetitive engineering efforts and improving design consistency [4]. But existing approaches generally focus on isolated calculations or individual engineering applications.

Although research exists on valve design and performance, limited literature addresses design automation frameworks specifically intended for manufacturing related engineering activities. Existing approaches focus on individual design parameters rather than providing a platform capable of supporting product development, design verification, manufacturing related activities.

Hence, a research gap exists in the development of standardized engineering tool capable of integrating multiple industrial standards while reducing engineering lead time and improving design consistency as well as repeatability.

3 Standards and Design Basis

3.1 ASME Section III

The ASME BPVC Section III provides us with rules or codes for design, fabrication and inspection of components used in high pressure and safety critical applications. It specifies rules for allowable stress, material requirements, and design criteria to ensure safe operations and structural reliability. This code is used for components where utmost safety is required including safety valves [5]. This study is based on rules of ASME Section III. All the parameters and safety considerations are as per the code to guarantee that the developed tool has reliable and compliant design results.

3.2 Pipe Dimensions – ASME B36.10

It provides us with standard dimensions for welded and seamless pipes including outside diameter and wall thickness based on DN number and pipe schedule number. These dimensions are important and are used to determine the geometry and compatibility of piping system and valve connection [6]. Developed tool has the data from ASME B36.10 as a reference and will provide us with accurate values of pipe dimensions and will eliminate all the possible errors that can be caused by human involvement.

3.3 Allowable Stress – ASME Section II Part D

It provides us allowable stress in MPa for materials for different operating temperatures. These values are important to ensure that the components are operating under safe stress limit. Allowable stress decreases as the temperature increases, it effects in material selection and thickness values [7]. This system provides us allowable stress data of chosen material, temperature automatically with the help of excel logic. The results provided by the tool are accurate and consistent without any manual interferences.

3.4 API 526

It specifies requirement of pressure relief valve, including its orifice size, set pressure, and other operational parameters. It also provides us with effects of back pressure which can impact valve performance and its discharge capacity [9]. The system provides us with back pressure values as per API 526 as per orifice type, material of bellow, and pressure rating to tackle the effects of backpressure

3.5 ASME B16.34

It provides us with pressure values of component in Bar (Gauge) and Minimum required thickness of shell at the body wall. It ensures valves can operate safely under specified conditions [8]. Template has reference tables from ASME B16.34 and excel logic which calculates pressure and minimum thickness using linear interpolation to provide us with exact valve for specific temperature and rating.

4 Methodology

4.1 System Architecture

There are three layers in the template: Input layer, processing layer, output layer. This type of system provides us with output which promotes clarity, efficient data to handle and systematically and automatically executed calculations.

- Input Layer: In this interface we define parameters such as pressure, temperature, material, sizes etc. The interface features with manual inputs for some parameters and dropdown list for some to ensure standard entries and minimize risk of errors.
- Processing Layer: This layer carries out all the calculation and logical operations. It includes mathematical formulas, standard data lookup tables, validation logic to provide us with accurate and consistent output. Standard code data is embedded within this layer so that it can provide us standard data according to given logic specifically generated based on required inputs [5,9].
- Output Layer: Displays results such as allowable stress, pipe dimensions, minimum thickness, primary and secondary pressure. Also indicates whether the output is as per guidelines or not.

4.2 Input Parameters

Below are the key input parameters required for calculations:

- **Pressure:** One of the important parameters which affects operating conditions, force calculations, thickness values and other standard values. [9].
- **Temperature:** Affects material properties, especially allowable stress, which generally decreases as temperature rises, influencing safety margins and thickness design [7].
- **Material:** Depending on material selection properties of material and allowable stress varies, these values are as per ASME Section II Part D [7].

- **Size:** Represented by nominal pipe diameter, it defines valve geometric dimensions, influencing flow characteristics and piping compatibility as specified in ASME B36.10 [6].

4.3 Mathematical Formulation

- **Allowable Stress Calculation** (per ASME Section II Part D) uses a formula integrating temperature-dependent stress values interpolated from standard tables:

$$S = S_{Low} + \frac{(T - T_{Low})}{(T_{High} - T_{Low})}(S_{High} - S_{Low})$$

Where:

S= Interpolated allowable stress
S_{Low}= Allowable stress at lower temperature
S_{High} = Allowable stress at higher temperature
T= Required design temperature
T_{Low} = Lower tabulated temperature
T_{High}= Higher tabulated temperature

- **Inlet Diameter and Pipe Thickness** (from ASME B36.10) are retrieved using lookup formulas based on nominal size and schedule:

$$D_i = (D_o - 2t)$$

Where:
Di = Inside diameter of pipe inlet, mm
Do = Outside diameter of pipe, mm
t = Wall thickness of pipe, mm

The balance between **pressure force** and **spring force** dictates valve operation, ensuring that the valve opens and closes reliably under specified conditions [10].

4.4 Design Workflow Algorithm

A systematic workflow is implemented to ensure consistency and repeatability throughout the safety valve design process. The algorithm integrates input parameters, standard data, and engineering calculations into a structured, step-by-step sequence:

1. Input design parameters such as pressure, temperature, material, and size.
2. Retrieve allowable stress values based on selected material and temperature [7].
3. Select pipe dimensions using standard lookup tables from ASME B36.10 [6].
4. Verify pressure ratings and operating limits according to applicable standards, including ASME Section III and ASME B16.34 [5,8].
5. Provide output results, such as geometric dimensions, stress values, and validation status indicators.

This structure ensures all calculations are systematic and are as per ASME Standards. It reduces manual labour, eliminates manual error, and enhances consistent and reliable safety valve design [4].

5 System Implementation

5.1 Excel Interface

The system is an excel based design calculation template, it is a structured interface for safety valve design. The input sheets act as a primary interaction layer, where user can enter key parameters such as pressure ratings, valve type, valve size, temperature, orifice type, set pressure, DN number and pipe schedule number. To ensure standard data entry and to minimize errors the input data sheet has selected open cells and for some parameters there are drop down lists as well.

The data provided as an input is used to calculate pipe dimensions, allowable stress and other standard design values. The overall system interface is as shown in the Table 1.

Table 1. Valve design input interface developed in Excel

Cover Page		
Input Data		
Description	Values	Units
Valve Type	Conventional Design	-
Size (Inlet × Outlet)	1 1/2" x 3"	inch
Inlet Rating	STD. 1500	-
Outlet Rating	STD. 150	-
Pressure Rating	STD. 1500 × STD. 150	-
Orifice	H	-
Orifice Diameter	25.38	mm
Set Pressure	155	Bar (g)
Back Pressure as per API 526	15.85	mPa (g)
Required Back Pressure	3	Bar (g)
Temperature (GAD)	200	˚C
DN	50	
Pipe Schedule No.	40	

5.2 Data Integration

The system provides standard data through provided excel logic, input data and reference data embedded into the lookup tables. As shown in the table 2 allowable stress is calculated considering reference tables from ASME Section II Part D. These values depend upon temperature, material of component. Data is achieved with help of excel logic by either matching the input or using linear interpolation when input varies from standard values in the reference tables [7].

Table 2. Allowable stress as per ASME Sec. II part D

Allowable Stress Calculation as per ASME Sec. II Part D (2021)		
Input Data		
Description	Values	Units
Temperature	200	˚C
Body Material	SA479 Gr.316	ASME Sec II Part D-2021 Table 2A
Allowable Stress: Body	134	MPa
Pipe Material	SA312 Gr.TP304L	ASME Sec II Part D-2021 Table 1A
Allowable Stress: Pipe	81.20	MPa
Bonnet Material	SA182 Gr.F316L	ASME Sec II Part D-2021 Table 1A
Allowable Stress: Bonnet	109.00	MPa
Nozzle Material	SA351 Gr.CF3M	ASME Sec II Part D-2021 Table 1A
Allowable Stress: Nozzle	133.00	MPa
Body to Bonnet Joint: Bolt Material	SA193 Gr.B8 CL2	ASME Sec II Part D-2021 Table 3
Bolt Size	20.00	mm
Allowable Stress: Bolt @200˚C	172.00	MPa
Allowable Stress: Bolt @38˚C	172.00	MPa
Disc Material	SA182 Gr.F316L	ASME Sec II Part D-2021 Table 1A
Allowable Stress: Disc	109.00	MPa
Spring Washer Material	SA479 Gr.316	ASME Sec II Part D-2021 Table 2A
Allowable Stress: Spring Washer	134.00	MPa
Spindle Material	SA479 TP410	ASME Sec II Part D-2021 Table 1A
Allowable Stress: Spindle	133.00	MPa
Adjusting Screw Material	SA479 Gr.316	ASME Sec II Part D-2021 Table 2A
Allowable Stress: Adjusting Screw	134.00	MPa

Pipe dimension data is matched using ASME B36.10 standard tables embedded into the system, allowing automatic selection of outer diameter and wall thickness corresponding to the selected nominal pipe size. This ensures proper pipe dimension selection resulting safe working of valve [6].

Table 3. Pipe schedule as per ASME B36.10

Pipe Dimenstions as per ASME B36.10 (2022)		
Input Data		
Description	Values	Units
Pipe Material	SA312 Gr.TP304L	-
Outside diameter of pipe inlet	60.32	mm
Wall thickness of pipe	3.91	mm
Outside diameter of pipe Outlet	60.32	mm
Wall thickness of pipe	3.91	mm

5.3 Automation

Automation in the system is achieved using Excel formulas and logical functions that can perform engineering calculations and standards-based rules. The system rapidly and automatically changes the output values whenever input parameters are changed, providing us with real time calculation and removing the need for manual recalculation. Logical functions manage the calculation flow and apply conditions according to selected parameters.

Visual Basic for Applications (VBA) is employed to enhance system functionality and user-friendly interface. VBA supports tasks like sheet control, and conditional data display by improving the template's overall performance. Automation is used to reduce manual error and manual efforts while calculation of design of safety valves [4].

5.4 Validation Logic

To ensure accuracy and reliability, the system uses validation logic given in ASME standards. Input validation restricts values to certain ranges, preventing invalid and unnecessary data from affecting design calculations.

The system also performs checks on calculated parameters such as pressure rating and minimum wall thickness based on ASME B16.34 and API 526 requirements. The verified outcomes can confirm whether the design meets safety standards given in ASME Section III [8,9]. If the results are within limits then they are highlighted with green cell otherwise they turn red, to indicate obtained results are not safe.

6 Case Study

6.1 Input Data

To show the effectiveness of the design calculation template, two case studies under specific conditions are mentioned below. The selected input parameters are almost similar to the industry and can indicate validation of the system.

Table 4. Result Validation of case studies

Parameter	Case 1	Case 2
Design Type	Conventional	Bellows
Material	SA182 Gr.316	SA182 Gr.316
Set Pressure (bar)	155	250
Temperature (°C)	200	300
Manual Allowable Stress (MPa)	134	121
Template Allowable Stress (MPa)	134	121
Error (%)	0	0
Manual Thickness (mm)	6.19	8.45
Template Thickness (mm)	6.19	8.45
Error (%)	0	0

These parameters are provided to the Excel system via input data sheet and drop down lists, ensuring standard data entry and compatibility with embedded standard reference data lookup tables. They are foundation for calculations and validation steps according to ASME standards [5,7].

6.2 Calculation Steps

Calculation process begins by identifying allowable stress for selected material and operating temperature. Using ASME Section II Part D reference data, the allowable stress for SA182 Gr.316 at 200°C is 134 MPa and at 300°C is 121 MPa, ensuring the material operations within safe stress limits [7].

Pipe dimensions are selected based on DN number and pipe schedule number on the cover page using ASME B36.10 standard data embedded into the system. The system automatically matches outer diameter and wall thickness, ensuring standard pipe dimensions [6].

Minimum required wall thickness of the valve body is calculated with reference to the standard data of ASME B16.34 embedded into the system, using manual input of inside diameter and outlet pressure class. The calculated minimum thickness of valve body is 6.19 mm & 8.45 mm respectively ensuring safe operations [9].

6.3 Output

The system provides us with final output using input parameters and validation of results:

- Maximum allowable stress: 134 MPa , 121 MPa(as per ASME Section II part D).
- Calculated minimum required wall thickness: 6.19 mm, 8.45 mm (meets design criteria as per ASME B16.34)

A validation status shows us whether the design calculated as per output provided by system is safe or not. In this research calculated values are as per ASME Section III guidelines are within acceptable limits. Hence the design is marked as “SAFE”. This concludes that the developed tool effectively provides or calculates output values which are as per standards.

Results match with standard requirements, showing us that the proposed approach has capability to perform accurate and efficient safety valve design calculations [5,9, 11,12].

7 Results and Validation

7.1 Comparison Table

To evaluate the effectiveness of the developed Excel based design template, results provided by template are compared with the values obtained with the help of traditional manual calculation method. This comparison is based on parameters such as allowable stress, pipe dimensions, minimum required wall thickness, calculation time and error probability which is shown in the table below;

Table 5. Comparison between results achieved manually & via Excel based tool

Performance Metric	Manual Method	Developed Framework
Standards Consulted	5 Documents	Embedded Database
Calculation Time	45 min	5–10 min
Manual Data Handling	High	Low
Repetitive Calculations	Required	Automated
Design Consistency	User Dependent	Standardized
Error Risk	High	Low

The results show us that the developed system provides or calculates the values similar to manual calculations. But the key difference is the speed of calculation of tool and manual method, while manual method requires concentration, awareness and more time for calculation, the tool calculates the values within the blink of an eye. Also, the tool eliminates all the possible chances of human error if provided with the correct input values for processing.

7.2 Accuracy Check

Developed system performance is then validated by comparing the values obtained and the values from the standard journals. It is noticed that the results are accurate and consistent for all the considered parameters like allowable stress, pipe dimensions, and wall thickness. Hence, we can conclude that the tool developed is reliable and consistent.

7.3 Performance

We can evaluate the performance of the template based on its efficiency, error reduction, consistency and repeated correct outputs. The main point observed is that the manual method needs almost 45 minutes the tool calculates all the calculations in 10 minutes based on the users data entry speed. If the data entry speed is increased then we can reduce calculation time of the tool as well.

While calculating manually we have to constantly keep an eye on the standard journals, there is no need for that while using the tool. The approximate time reduced is almost 75%.

Error reduction is the one of the most important benefits of the system. Manual method will always cause some errors, but there is no chance of error in the system if provided with the correct input and reference data.

8 Results & Discussion

The results demonstrate that the developed framework successfully performs all required design calculations while maintaining compliance with applicable engineering standards. But our proposed system completes all the calculations within given time is case study. It also indicates whether the design is safe or not and our values are as per standards or not. It reduces all the possibilities of manual error, reduces manual labour significantly, and provides us accurate, consistent output [7].

Allowable stress decreases as temperature increases. Wall thickness properties also change based on input. Higher the operating pressure greater the generated pressure force on the valve so wall thickness increases as the operating pressure rating increases. [9].

9 Conclusion

The study shows us successful development of safety valve design calculation template which is based on excel logic, design formulas and ASME Standards. The results shows us that the tool provides us accurate and precise values if provided with correct inputs. The developed framework reduced engineering calculation time by approximately 75% compared with conventional manual calculation methods. Results obtained from the automated framework showed complete agreement with manually verified calculations. Eliminates the chance of human error, reduces manual efforts. The system has user friendly interface and ease in use of the tool, as everything is simple and sorted.

All the results match the values given in the ASME & API Journals. The system offers practical tool that is ready to be used in the industry where accuracy, repeatability, efficiency, consistency are given utmost priority.

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