

LIQUID SURGE ANALYSIS**JGS 210-120-1-74E**

Rev.0 DATE JUL.-31-'96

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1. SCOPE

This standard practice provides the guidelines for the liquid surge study in refineries, petrochemical plants and similar plants.

For details, reference shall be made to SIGTTO and ISGOTT, etc.

Liquid surge is the name given to the distinctive pressure fluctuations caused by the fluctuations of the liquid flow rate in the pipe due to opening and closure of a valve, pump start and stop, etc. This phenomenon can lead to high stressing on piping and equipment with the consequent possibility of liquid leakage.

2. WORK PROCEDURES**2.1 General Work Procedures**

- (1) Prepare the postulated surge study scenarios in consultation with the client, considering the process operating procedures especially paying attention to the emergency shutdown, process upsets, inadvertent operation and mal-fuctioning of equipment and control system.
- (2) According to the above scenarios, establish computer calculation models and perform the surge calculation using computer program.
- (3) Calculate the maximum surge pressure at various piping locations in each scenario according to the given operating conditions, liquid properties, process flow scheme, equipment characteristics, piping specifications such as pipe diameter, wall thickness, pipe length, etc. including piping routing an up-down elevations.
- (4) Specify the design pressure of the piping system to incorporate the calculated maximum surge pressure in accordance with the local and/or authorized design codes such as ANSI B31.3, B-31.4, etc.
- (5) If the specified design pressure is not acceptable to the subject system, find the most favorable solution by changing the previous study scenarios within the agreed process operating philosophy and so on.

General work procedures of liquid surge study are described in Figure 2.1.

Transient force shall be calculated for the case to find if the force is within the allowable limit. The allowable limit shall be decided on discussion among process engineer, piping engineer and civil engineer. Typical objectives to execute transient force calculation are large pipes on long trestle, piping systems which hydraulic shocks due to check valve slamming, liquid column rejoining, etc. were not inevitable. The results shall be forwarded to piping department for further dynamic stress studies.

2.2 Input to the Study

- (1) PFD, UFD, PEFS
- (2) Hydraulic calculation data
 - physical properties of liquid(density, viscosity, vapor pressure , elastic modulus)
 - flow distribution and hydraulic calculation
 - pump specification(pump performance curves)
 - valve specification(valve type - valve characteristics, valve closing/opening speed)
 - other equipment data such as H/E, R/O, etc.
 - specifications of pressure, flow and level controllers, flow limitters, etc.
- (3) Control philosophy
 - control philosophy(normal start-up, normal shutdown, emergency shutdown, etc.)
 - ESD sequence, logic diagram and timing chart
 - ship-shore-ESD linkage
- (4) Piping layout
 - piping class specifications
 - plot plan indicating piping route
 - terrain profile
 - isometric drawing for the case of transient force calculations

2.3 Output from the Study

(1) Surge calculation

- Time history of pressure and flow rate
- Hydraulic grade line - maximum and minimum pressure profile along the pipe line
- Dynamic behavior of equipment such as pump, valve, pressure relief valve, surge tank, etc.

(2) Output

- Maximum pressure and minimum pressure due to pressure surge
- Equipment specifications to protect piping system from over pressure - valve closure time, capacity of surge protection equipment such as pressure relief valve, surge tank, vacuum breaker, etc.
- Assessment to the pipeline control philosophy from the liquid surge stand point of view.

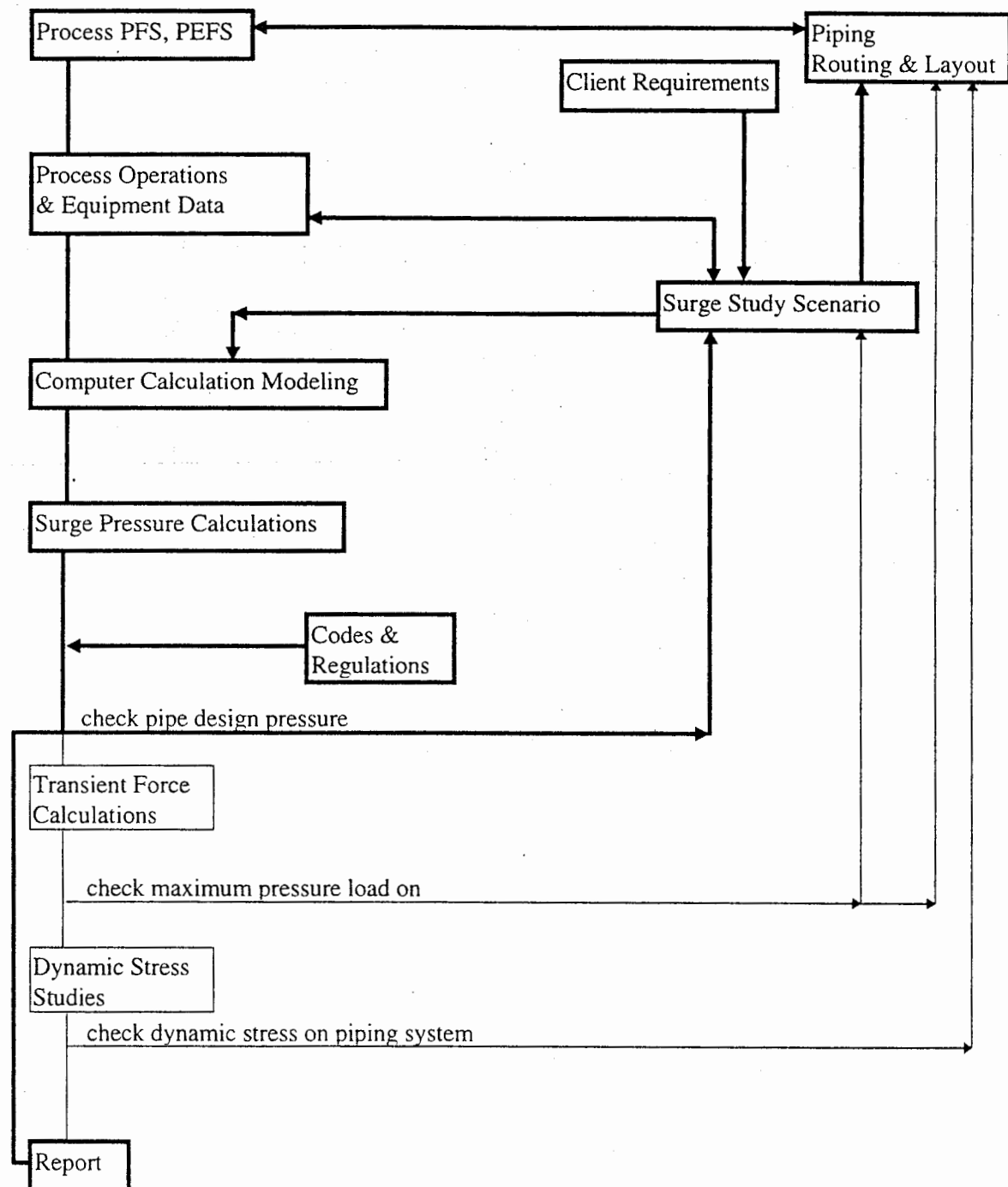


Figure 2.1 General Procedures for Surge Study

3. LIQUID SURGE STUDY

3.1 Wavespeed inside Pipe

Liquid surge inside pipe is caused by rapid changes of the liquid flow rates. The pressure surge front goes through pipelines as pressure waves, and is reflected backwards. In this regard, wavespeed (sonic velocity inside pipe) is the most important for liquid surge studies.

The velocity of pressure wave inside pipe is defined as follows:

$$a = \frac{1}{\sqrt{g \left(\frac{1}{K} + \frac{1}{E} \frac{D}{t} C \right)}} \quad (1)$$

where

a = wavespeed	(m/s)	E = pipe material Young's modulus	(kgf/m ²)
γ = liquid density	(kg/m ³)	D = pipe inside diameter	(mm)
K = liquid bulk modulus	(kgf/m ²)	t = pipe wall thickness	(mm)
g = gravity constant	(m/s ²)		
C = pipe constraint coefficient	(Usually, 1.0 is applicable)		

Values of ρ and K				Values of E		
Liquid	T (°C)	ρ (kg/m ³)	K (kgf/m ²)	Material	T (°C)	E (kgf/m ²)
LNG	-160	463.2	7.50×10^7	Carbon steel	20	2.14×10^{10}
LPG	20	543.1	3.63×10^7	SUS 304	-162	2.17×10^{10}
	20	552.8	4.07×10^7		20	2.04×10^{10}
Methane	-160.5	420.8	7.73×10^7	SUS 310	-162	2.08×10^{10}
Ethane	-89	544.5	9.44×10^7		20	1.21×10^{10}
Propane	-42	581.4	8.66×10^7			
n-Butane	-1	583.2	7.02×10^7			
n-Pentane	20	626.0	6.80×10^7			
HC condensate	45	707.4	8.75×10^7			
Ethylene	-108	579.7	2.39×10^8			
	-34	457.7	3.54×10^8			
Propylene	-43	583.5	1.72×10^8			
	0	527.0	5.74×10^7			
Gasoline	34	803.0	1.27×10^8			
Kerosene	20	810.0	1.45×10^8			
Heavy oil	50	954.0	1.79×10^8			
Crude oil	15	889.0	1.90×10^8			
Water	20	998.3	2.25×10^8			
	180	886.9	1.69×10^8			

Wavespeed becomes slower in the case of the existence of vapor cavities in the pipe. One(1) volume percent vapor cavities dispersed in liquid might decrease the wavespeed down to 20 - 30 percent of the speed obtained by the equation (1). This effect is beneficial in the reduction of surge pressure.

3.2 Valve Stroking Time

(1) Effective valve stroking time

Effective valve stroking time varies depending on the pressure loss of the pipeline and valve types. Figure 3.1 shows the conventional chart for estimating the effective valve stroking time T_e .