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Optimization of Different Parameter of Cold Storage for Energy Conservation

Amit M Patel[1], Prof. R I Patel[2]

*(ME-Student, Department of Mechanical Engineering, GEC Dahod, India)

**(Asst. Professor, Department of Mechanical Engineering, GEC Dahod, India)

ABSTRACT

As the demand for refrigeration and Air conditioning has been increased during the last decade, the cold storage system can be used to the economic advantage over conventional plants. Energy conservation is required in the cold storage system so The Design of Experiment is used to Optimization of different parameters of cold storage on the bases of performance experiments. In This Experiment, three levels of Thickness, Area of wall and Compressor are kept as the control parameters, The Insulating wall material was taken as PUFF, and different energy were taken as a result in the experiment, The Objective of this paper is Optimize different parameters in the cold storage. The various tools of DOE are used for analyze the final results of the experiment with the help of Graphs. The analysis is being done with the help of Minitab-15 software. The analysis of variance ANOVA is also performed as identified the statistical significance of parameters. The result of the experiments are the optimum value of insulating thickness, energy consumption rate with the help of ANOVA, After the using Taguchi method determine the feasibility of improving cooling capacity of cold storage, establish the mathematical models relating the cold storage performance parameters & control parameters by regression analysis and obtained set of optimal cold storage parameters for better performance.

Key words: **Insulation Thickness, area of wall, compressor and energy, Optimization, Cold storage,**

I. INTRODUCTION

Cold Storage is a special kind of room, the temperature of, which is kept very low with the help of machines and precision instruments. India is having a unique geographical position and a wide range of soil thus producing variety of fruits and vegetables like apples, grapes, oranges, potatoes, chilies, ginger, etc. Marine products are also being produced in large quantities due to large coastal areas. The present production level of fruits and vegetables is more than 100 million MT and keeping in view the growth rate of population and demand, the production of risible commodities is increasing every year. The cold storage facilities are the prime infrastructural component for such perishable commodities. Besides the role of stabilizing market prices and evenly distributing both on demand basis and time basis, the cold storage industry renders other advantages and benefits to both the farmers and the consumers. The farmers get opportunity of producing cash crops to get remunerative prices. The consumers get the supply of perishable commodities with lower fluctuation of prices. Commercially apples, potatoes, oranges are stored on large scale in the cold storages. Other important costly raw materials like dry fruits, chemicals, essences and processed foods like fruit juice/pulp, concentrate dairy products, frozen meat, fish and eggs are being stored in cold storages to regulate marketing channels of these products.

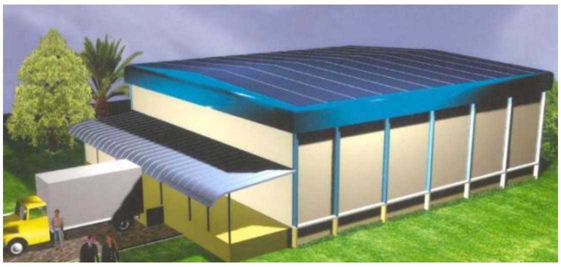

Fig 1.1 Cold Storage

II. LITERATURE REVIEW

M.S. Soeylemez et al (1997)[1] has suggested A thermo economic optimization analysis is presented yielding a simple algebraic formula for estimating optimum insulation thickness for refrigeration applications. The effects of design parameters on the optimum insulation thickness are investigated for three test cities using an interactive computer code written in Fortran 77. The equivalent full load hours method is used to estimate the energy requirements. Merrick Burden et al (2004)[2] has suggested Frozen storage is an integral part of effective food distribution. In general, both food quality retention and storage costs will increase as storage temperatures decrease. Mashud Ahmed et al (2009)[3] has suggested A general estimate shows that 80% of communities across the United States receive their goods exclusively by transport trucks, of which a significant number are climate-controlled because they carry perishable goods, pharmaceutical items and many other temperature-sensitive commodities. N.Yusoff et al(2010)[4] has suggested that study presents a procedure for selecting optimization variables in a Refrigerated Gas Plant(RGP) using Taguchi method with L27(39) orthogonal arrays. A dynamic RGP model developed under HYSYS environment is utilized as a test bed. This model comprises 762 variables and 21 regulatory control loops. However only 9 variables or factors with three level each are studied to determine their relative significance in maximizing RGP profit.

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III. EXPERIMENTAL SET UP

The experimental set up at Super Refrigeration, Near Shyamal Cross Road ,Ahmedabad on prepared model of cold storage, The compressor, condenser unit, evaporation unit, expansion valve were used and special experimental cold storage box was attached with refrigeration system , the device, Watt meter and thermo couple are to attached with this cooling unit here the design experiments is based on Taguchi Methodology A 3-Factor and 3-level,L9 Orthogonal array design is used to conduct the experiments. The levels of Thickness are 0.050, 0.075 and 0.100 meter. Area of wall are 0.96, 1.5 and 2.16 m2 and Compressor 0.100, 0.125 1nd 0.167 HP, the inside Temperature is kept constant at 2° C through out the experimentation. Here total L9 = 9 experiments will conducted.

Experimental Constant
Inside temperature:- 2˚C
Thermal conductivity :- 0.025 W/m k
Material:- PUFF

Parameter and Range Selection

To select the parameters and its levels for experimentations, several exploratory experiments were conducted to determine important control factors. Out of several available controllable input parameters on the cold storage, following parameters were selected with maximum feasible range.

Symbol	Control Factor	Unit	Level 1	Level 2	Level 3
A	Thickness	Mt	0.050	0.075	0.100
B	Area of wall	Mt	0.96	1.5	2.16
C	Compressor	HP	0.100	0.125	0.167

Table 1 Parameter and Range selection

IV. INDENTATIONS AND EQUATIONS

*Calculation of Heat Transfer through wall, Ceiling & Floor

$Q = UA(To - Ti)$
Where,
A = Area of Wall, m2
U = Over all Heat Transfer Co-efficient KJ/s m2 K
Ti = Internal Temperature °C
To = External Temperature °C

$$U = \frac{1}{\left(\frac{1}{H1}\right) + \left(\frac{X1}{K1}\right) + \left(\frac{X2}{K2}\right) + \left(\frac{X3}{K3}\right) + \left(\frac{1}{H2}\right)}$$

H1= Outside heat transfer Co-efficient
H2= Inside heat transfer Co-efficient
Ki= Thermal conductivity of materials
Xi= Thickness of Materials

*Calculation of Total Refrigeration required

$$Total\ refrigeration\ required = \frac{Total\ heat\ removed}{3.5}$$

Ton of refrigeration = 3.5 KJ/s

The total amount of electrical energy consumption of a typical refrigeration system may be determined by the equivalent full loads hours energy estimation as follows[1]

$$E = Q \times \frac{\Delta t}{COP}$$

E= Annual total energy consumption of refrigeration system (kw/h)
Δt =Equivalant full load hours of operation of refrigeration system (hrs)
COP=Co-efficient of performance of refrigeration plant

V Figures and Tables

Selection of Orthogonal Array

Knowing the number of parameters and the number of levels, the proper orthogonal array can be selected. The number of process parameters in our experimental runs is three. i.e. Thickness of wall with 3 levels, Area of wall with 3 levels and Compressor with 3 levels. The numbers of levels in all control factors are equal. Therefore 3-level orthogonal is required in our experimental plan.

The L9 orthogonal array as shown in table 6 for All factor 3- levels design.
Therefore total 9 x 3 = 27 experimental runs are performed for the observations

Observation Tables

Exp. No.	Control Parameter			Energy	Heat Transfer rate
	Thickness	Area of wall	Compressor	Watt	W/m K
1	0.050	0.96	0.100	258	14.56
2	0.050	1.5	0.125	383	23.17
3	0.050	2.16	0.167	502	32.96
4	0.075	0.96	0.125	172	10.4
5	0.075	1.5	0.167	241	15.78
6	0.075	2.16	0.100	409	22.73
7	0.100	0.96	0.167	119	7.78
8	0.100	1.5	0.100	222	12.33
9	0.100	2.16	0.125	290	17.23

Table: Observation table

In this study most important output performances in Cold Storage such as Energy consumption(E), Heat Transfer Rate(Q) are considered for optimizing Cold storage parameter. The Energy (E) value (in Watt) was obtained by using watt meter, The Heat Transfer Rate was measured by using Thermo couple The Heat Transfer Rate (HTR) is calculated as,

Q=UAΔT----------------------(1)

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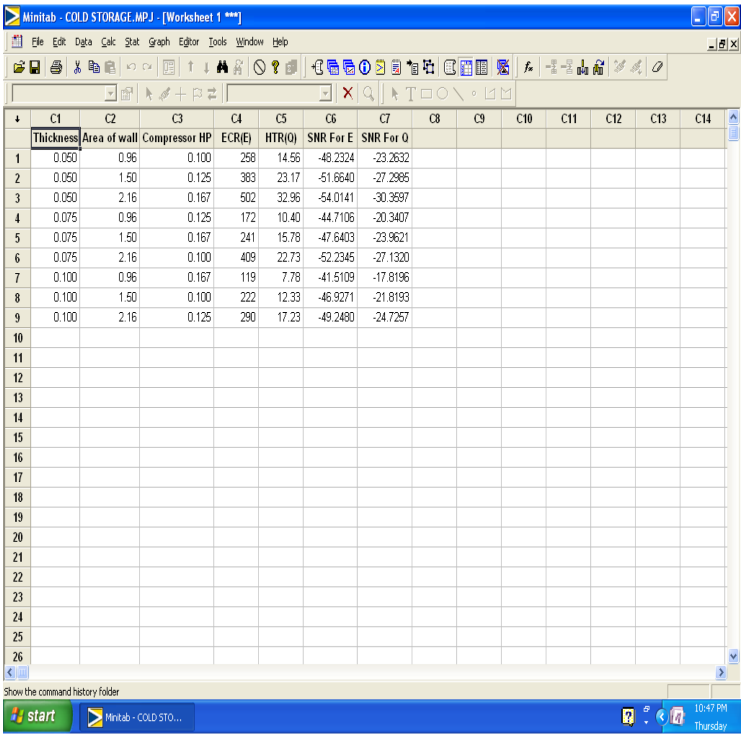
Where U= Thermal Coefficient of wall, A= Area of wall, ΔT= Temperature Difference

About Analysis software MINITAB

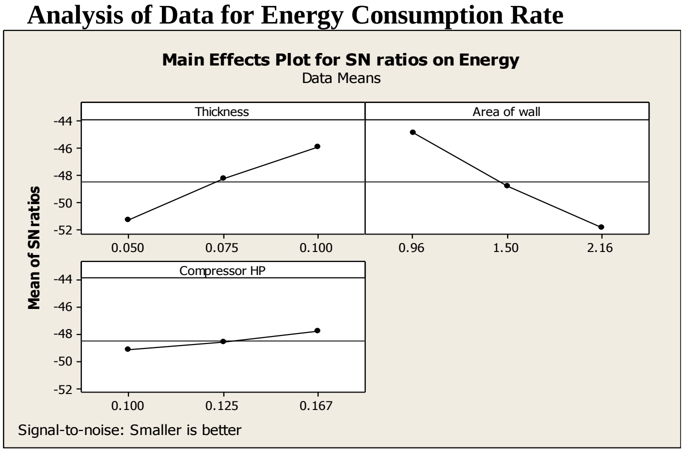
Minitab is a statistics package used for analysis of experimental data. It was developed at the Pennsylvania State University by researchers Barbara F. Ryan, Thomas A. Ryan, Jr., and Brian L. Joiner in 1972.

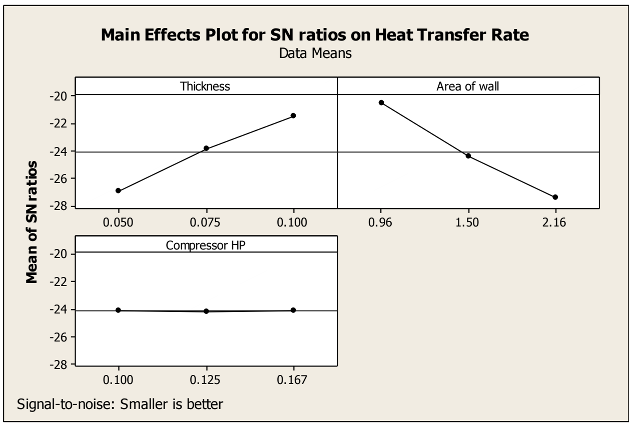
The goal of robust experimentation is to find an optimal combination of control factor settings that achieve robustness against (insensitivity to) noise factors. MINITAB calculates response tables and generates main effects and interaction plots for Signal-to-noise ratios (S/N ratios) vs. the control factors.



It provides standard orthogonal array for Taguchi methodology for experiment design. It also performs regression analysis to establish relation between two or more variables. It also helps in generating various types of tables and graphs.

Analysis of Data for Energy Consumption Rate





For the individual response maximization or minimization, chart 1 & 2 gives optimum value of each control factor. Chart interprets that Level A3,B1,C3 gives minimum result of Energy,

Analysis of Variance for Energy

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Thickness	2	44630	44630	22315	15.12	0.062
Area of wall	2	71038	71038	35519	24.07	0.040
Compressor	2	328	328	164	0.11	0.900
Error	2	2951	2951	1475		
Total	8	118946				

Table: Analysis of Variance for Energy
R-Sq = 97.52% R-Sq(adj) = 90.08%

Analysis of Variance for Heat Transfer Rate

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Thickne	2	191.162	191.162	95.581	16.03	0.059
Area of wall	2	269.606	269.606	134.803	22.61	0.042
Compres	2	9.080	9.080	4.540	0.76	0.568
Error	2	11.923	11.923	5.961		
Total	8	481.771				

Table: Analysis of Variance for Heat Transfer Rate
R-Sq = 97.53% R-Sq(adj) = 90.10%

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Exp No	Thickness	Area of Wall	Compressor	SNR_Energy	SNR_Heat transfer rate
1	0.050	0.96	0.100	-48.2324	-23.2632
2	0.050	1.5	0.125	-51.6640	-27.2985
3	0.050	2.16	0.167	-54.0141	-30.3597
4	0.075	0.96	0.125	-44.7106	-20.3407
5	0.075	1.5	0.167	-47.6403	-23.9621
6	0.075	2.16	0.100	-52.2345	-27.1320
7	0.100	0.96	0.167	-41.5109	-17.8196
8	0.100	1.5	0.100	-46.9271	-21.8193
9	0.100	2.16	0.125	-49.2480	-24.7257

Table: S/N Ratio for Response parameters

S/N ratio for response parameters as shown in table can be calculated using above equations. However we have obtained it using MINITAB 15 software.

Normalization of S/N Ratio for Response parameters

Step 2: In the grey relational analysis, a data pre-processing is first performed in order to normalize the raw data for analysis. Normalization is a transformation performed on a single data input to distribute the data evenly and scale it into an acceptable range for further analysis. In this study, a linear normalization of the S/N ratio is performed in the range between zero and unity. S/N ratio for response parameters as shown in table are normalized for further analysis using following equations.

Exp No	Thickness	Area of Wall	Compressor	Normalized SNR of Energy	Normalized SNR of Heat transfer rate
1	0.050	0.96	0.100	0.4624	0.5659
2	0.050	1.5	0.125	0.1880	0.2441
3	0.050	2.16	0.167	0.0000	0.0000
4	0.075	0.96	0.125	0.7441	0.7990
5	0.075	1.5	0.167	0.5098	0.5102
6	0.075	2.16	0.100	0.1423	0.2574
7	0.100	0.96	0.167	1.0000	1.0000
8	0.100	1.5	0.100	0.5668	0.6811
9	0.100	2.16	0.125	0.3812	0.4493

Table 14 Normalization of S/N Ratio for Response parameters

Calculation of GRC and GRG for Response parameters

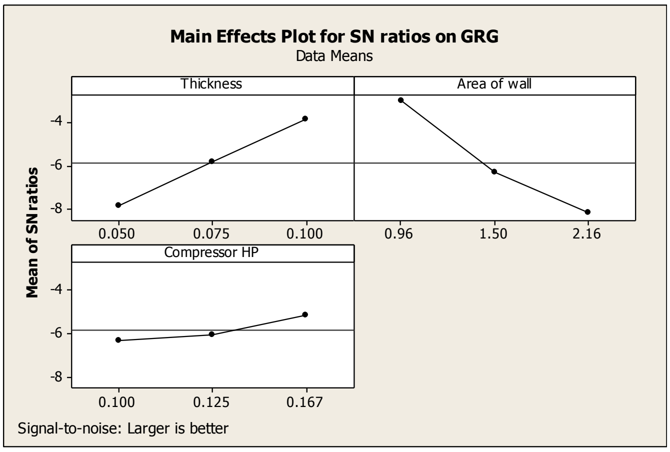
Exp No	Control Factor			Grey Relation Coefficient		GRG
	Thickness	Area	Compressor	GRC Energy	GRC HTR	
1	0.050	0.96	0.100	0.4819	0.5353	0.5086
2	0.050	1.5	0.125	0.3811	0.3981	0.3896
3	0.050	2.16	0.167	0.3334	0.3334	0.3334
4	0.075	0.96	0.125	0.6615	0.7132	0.6873
5	0.075	1.5	0.167	0.5049	0.5051	0.5050
6	0.075	2.16	0.100	0.3683	0.4024	0.3853
7	0.100	0.96	0.167	1.0000	1.0000	1.0000
8	0.100	1.5	0.100	0.5358	0.6105	0.5732
9	0.100	2.16	0.125	0.4469	0.4759	0.4614

Table Calculating GRC and GRG for Response parameters

The higher grey relational grade reveals that the corresponding experimental result is closer to the ideally normalized value. Experiment 7 has the best multiple performance characteristic among 9 experiments, because it has the highest grey relational grade shown in Table 15.The higher the value of the grey relational grade, the closer the corresponding factor combination is, to the optimal. A higher grey relational grade implies better product quality; therefore, on the basis of the grey relational grade, the factor effect can be estimated and the optimal level for each controllable factor can also be determined.

Main Effect of Factor on Grey Relation Grade

Following graph shows the grey relational grade graph. Basically, the larger the grey relational grade, the better is the multiple performance characteristic.



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For the combined responses maximization or minimization, chart gives optimum value of each control factor. Chart interprets that Level A3, B1 and C3 gives optimum result. The mean of the grey relational grade for each level of the other Cold storage parameters can be computed in a similar manner. The mean of the grey relational grade for each level of the Cold storage parameters is summarized and shown in the following Table.

Symbol	Control Factor	Level-1	Level-2	Level-3
A	Thickness	0.4105	0.5259	**0.6782**
B	Area of wall	**0.7320**	0.4893	0.3933
C	Compressor HP	0.4890	0.5128	**0.6128**

Table 16 Main Effects of Factors on Grey Relational Grade

Mathematical Model The mathematical model for predicting the response parameters in Cold storage can be derived using methods like Regression analysis.

Regression Equation for Energy

The Regression Equation is

Energy(E) =280 – 3143 Thickness + 181 Area of wall - 106 Compressor HP

Predictor	Coefficient	SE Coef	T	P
Constant	279.54	65.56	4.26	0.008
Thickness	-3413.3	470.10	-7.26	0.001
Area of wall	181.04	19.55	9.26	0.000
Compressor HP	-106.4	347.10	-0.31	0.772

Table Regression coefficient for Energy

R-Sq = 96.5%

In the regression analysis, the P value of factors, Thickness and Area of wall are less than 0.05, therefore these factors are significant. The co-efficient of determination (R2) indicates the goodness of fit for model. The value of R2 is 96.5% which indicates that model is fit for prediction.

Regression Equation for Heat Transfer Rate

The regression equation is

HTR(Q) = 12.3 -222 Thickness +11.2 Area of wall + 35.5 Compressor HP

Predictor	Coefficient	SE Coef	T	P
Constant	12.302	4.344	2.83	0.037
Thickness	-222.33	31.14	-7.14	0.001
Area of wall	11.153	1.295	8.61	0.000
Compressor HP	35.48	22.99	1.54	0.184

Table.18 Regression coefficient for Heat Transfer Rate

R-Sq = 96.2%

The results of analysis indicate that the compressor HP is not much significant in Heat Transfer Rate. Here the value of R2 is 96.2%, which is quiet high; therefore model is suitable for result prediction.

	Process Parameter	
	Orthogonal Array	Grey Relation Design
Level	A3 B1 C3	A3 B1 C3
ECR	119	119
HTR	7.78	7.78

VII. CONCLUTION

In the Present Research work there was developed cold storage model at super Refrigeration and also developed Refrigeration system, both are attached with each other for experiment. In this work our main objective is to Optimum insulation thickness, Area of wall, compressor capacity of cold storage with the help of Taguchi method, There was Three factor Thickness, Area of wall and compressor consider and take Three level each 0.050,0.075,0.100 and 0.96 1.5 2.16 and 0.100, o.125, 0.167 in Taguchi Method. we are using L9 Orthogonal Array Design. In the research work there is using ANOVA for Develop different Graphs of S/N Ratio ,here concluded that orthogonal array and Grey relation design both are gave same result as best optimum value of Thickness 0.100 Mt, area of wall 0.96 Mt and compressor 0.167 HP and also study of Regression analysis to develop Mathematical model for calculating direct optimum value of all parameters

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