AN INCONVENIENT TRUTH

Bad cold chain practices at every level
Customer (The ultimate sufferer)

THE NEED & NECESSITY
Cold Storage Development For Perishables

WHAT IS THE EXISTING SITUATION

- Not efficient / Attempting efficiency – Cold Chain Practice.
- Voluminous produce – limited availability
- Quality not so good always
- Set back to Growers – imports
- Product Wastage on field
- Not proper / efficient storage

IMPROPER COLD STORAGE

INSULATION PURPOSE

- Initially when Cold Storage starts, Refrigeration equipment brings down temp.
- Subsequently insulation maintains the temperature.

CONVENTIONAL COLD STORE

The basic rules for insulation system are:

- Using good insulating material having a high insulating value, characterized by a low thermal conductivity
- Protection to the insulant against vapour ingress, by providing a Vapour Retarder applied directly to the wall to restrict migration of ambient atmospheric moisture into the cold room interior.
- Use an interior lining on insulation essentially to prevent mechanical damage

Plaster + Brick + Plaster + VB + Insulation + Finish
Approx. 360mm wall

Treat a commodity like human being
EXISTING COLD STORE – PROBLEMS,
CONVENTIONAL PRACTICE

Sequential application of vapor barrier, insulation & plaster finish

What about moisture ingress from inside & life of plaster finish

Basic Thermal & Civil Engg. Design problem

EXISTING COLD STORE – PROBLEMS

CAUSES OF THERMAL INSULATION SYSTEM FAILURE
- Continuous moisture ingress through plaster
- Insulation becoming wet & resistivity decreases
- Plaster chipping off
- Vapour barrier becomes weak
- Formation of cold spots
- Deterioration & failure of Thermal Insulation System

1 % OF MOISTURE INGRESS = 5 % REDUCTION IN ‘R’ VALUE

EXPANDED POLYSTYRENE (EPS)
TECHNICAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>18 to 22 kg/m³. Higher densities available on request</td>
</tr>
<tr>
<td>Temperature range</td>
<td>-200 deg.C to 90 deg.C</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>The air entrapped within the minute closed cells impart to the material its extraordinarily low thermal conductivity 0.024 W/mk at 10°C mean temp.</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>0.7 to 1 kg/m² at 10% deformation</td>
</tr>
<tr>
<td>Cross Breaking Strength</td>
<td>1.4 to 1.6 kg/m²</td>
</tr>
<tr>
<td>Water Absorption (after 24 hrs. immersion)</td>
<td>Less than 0.5% by volume</td>
</tr>
</tbody>
</table>

EXPANDED POLYSTYRENE (EPS)
TECHNICAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Inertness</td>
<td>Unaffected by water, acids, alkalies, alcohols and most oils of vegetable and animal origin. Soluble in aliphatic, aromatic and chlorinated hydrocarbons, ketones, ethers, esters, petrol, turpentine, concentrated sulphuric and nitric acids</td>
</tr>
<tr>
<td>Handleability</td>
<td>Easily cut with a knife and readily applied with solvent free bitumen and adhesive</td>
</tr>
<tr>
<td>Standard Sizes</td>
<td>Slabs – 1M x ½ M of thickness 25mm to 100mm &amp; Pipes – 1½M length of thickness 15 to 150mm. Other sizes and thicknesses available on request.</td>
</tr>
</tbody>
</table>
| Draw backs           | • Moisture gets entrapped between cells and ice formation, leads to failure gradually.  
  • Low density  
  • Poor compressive strength  
  • Poor adhesion  
  • Lower temp. rating |

INSULATION LIFE

- Insulation needs to be properly fixed to surface
- Insulation needs to be covered & protected
- Cold Insulation needs vapour barrier on warm side

- Cold storage Insulation needs vapour barrier on both sides to counter moisture attack on both sides.
- Thermal Engineering issue

Suppose if Insulation is changed

Changing from Open Cell Structure to Closed Cell Insulation materials
- Polyurethane Foam Slabs with aluminium foil
- Cold adhesives
- Proper Thickness (70 ->85-90% RH)
- PPGI sheet finish
- Polymerized plaster
Suppose if Insulation is changed

- Jointing problem will persist.
- PPGL sheet finish, conduction losses from back up support / cold spots
- Moisture ingress thru joints.
- Labour intensive application.
- Partial solution
- Poor aesthetics
- Polymerized plaster & PUF

Polyurethane & Polyisocyanurate Foams:
- Manufactured out of a very fast chemical exothermic reaction between two chemicals in presence of a blowing agent resulting into a polymer matrix & gas filled closed cells all around

Basics

Gas filled air cells has very low conductivity which reduces heat conduction
- Smaller size of cells reduces convection
- Every cell acts as a barrier to radiative heat loss
- Some air does enter the blowing agent cells and fills up thru aging
- Thermal conductivity slightly changes – aging (0.017 to 0.021 W/mK)

Polyurethane & Polyisocyanurate Foams -
- Lowest thermal conductivity (0.021 W/mK)
- Adequate density (32-36 kg/m3 for Slabs, 40-45 kg/m3 for panels)
- Higher temperature rating (110-140 deg. C)
- Higher Resistance Values
- CFC, HCFC & ZERO ODP
- Low embodied energy
- Indigenously manufactured (within 500 kms. any site)
- Green Insulation – 5 Points

Extruded Polystyrene Foams:
- Light Petrochemical beads / globules compressed & cured with steam
- Expanded has permeable faces & Extruded partially / easily damageable impermeable faces
- Lower temperature ratings 70°C (max.)
- Higher manufacturing / embodied energy
- Low density
- Extruded still primarily imported
- Primarily cold climate product

High Performance Closed Cell Insulation Material

- Extruded Polystyrene Foams -
- Lower temperature ratings 70°C (max.)
- Higher manufacturing / embodied energy
- Low density
- Extruded still primarily imported
- Primarily cold climate product

UPGRADED INSULATION SYSTEM

ETICS : Upgrade conventional insulation practice

1) Masonry
2) Adhesive
3) Polyurethane/PIR Foam
4) Basecoat
5) Fiber mesh
6) Top Coat
**UPGRADED INSULATION SYSTEM**

1. External Plaster
2. Bricks
3. Special adhesive for PUF
4. PUF Insulation slab
5. Polymerized Plaster or Tile

**Insulation applied on Wall Existing Cold Stores**

- Direct application of PUF insulation on plastered walls from inside or outside.
- Polymerized Plaster with reinforcement.
- Painting

**Existing Cold Stores with sound civil construction – Revamping of Insulation**

**REVAMPING OF EXISTING COLD STORES**

**WALL INSULATION WITH PUF / PIR SLABS**

APPLICATION OF PRIMER COAT

APPLICATION OF ADHESIVE

FIXING OF SLAB ON TO THE WALL
REVAMPING OF EXISTING COLD STORES

WALL INSULATION WITH PUF / PIR SLABS
FIXING OF SLAB ON TO THE WALL

WALL INSULATION WITH PUF / PIR SLABS
STAGGERED JOINTS

WALL INSULATION WITH PUF / PIR SLABS
APPLICATION OF BASE COAT

WALL INSULATION WITH PUF / PIR SLABS
APPLICATION OF BASE COAT

WALL INSULATION WITH PUF / PIR SLABS
FIXING OF REINFORCEMENT MESH

WALL INSULATION WITH PUF / PIR SLABS
FIXING OF REINFORCEMENT MESH
REVAMPING OF EXISTING COLD STORES

WALL INSULATION WITH PUF / PIR SLABS

APPLICATION OF TOP COAT

REVAMPING OF EXISTING COLD STORES

WALL INSULATION WITH PUF/PIR (EXTERNAL)

FINAL FINISH

REVAMPING OF EXISTING COLD STORES

WALL INSULATION WITH PUF/PIR (EXTERNAL)

FINAL FINISH

What is the Solution to achieve efficiency in Cold Store construction

MODERN PRACTICE IN COLD STORE CONSTRUCTION

Total thickness: 360mm

Thickness 80 to 100/150 mm

Replaced with

PUF Panels

Conventional

Modern

Insulation applied inside Existing Cold Stores

- Direct application of PUF insulation on plastered walls from inside.
- Polymerized Plaster with reinforcement.
- Painting

Existing Cold Stores with sound civil construction – Revamping of Insulation
DESIGN TREND IN MODERN COLD STORES

MATERIALS:
- Prefabricated Polyurethane Foam sandwich panel
- Metal sheet finish – solid barrier on both sides
- Energy efficient insulation
- Scientifically designed edges, camlocks
- Steel Structure / PEB

1. PUF Panel
2. Metal facing

ADVANTAGES:
- Thermal & vapour barrier metal finish panels
- Easy to install
- Less labour intensive
- Fast construction
- Energy efficient
- In practice in India since 1994 / 97
Modern practices in cold store construction

- RCC work is replaced by steel columns and purlins – a Pre-engineered Building Technology.
- Brick walls & Insulation, False Ceiling with Insulation replaced by Polyurethane Sandwich panels directly fixed to the columns.
- 4-6 tiers can be formed of height 7 feet each.
- Maintaining an air gap of 1-2 feet on the sides and 4 feet for stair case.

Modern practices in cold store construction

Wall insulation is 80mm thick Rigid Polyurethane Foam Panel, with 0.5mm thick Colour Coated and Galvanized Sheet on both sides, with Tongue & Groove jointing detail and cam-lock arrangement.

Ceiling Panels are 100mm thick.

Floor is 60mm EPS as in Conventional System or PUF slabs

Rain Guard profile sheet

Insulated doors

Energy Efficient Refrigeration system

Modern practices in cold store

Features

Lloyd Panel System- Prefab Panels

Panel Dimensions

- Length: 12 mtr. (max.)
- Width: 0.6 – 1.2 mtr.
- Thickness: 50, 60, 80, 100, 120, 150, 200mm
- Shape: Straight, L shape for corners

ELEMENTS OF A MODERN COLD STORE

PEB Steel structure framing

PRE-ENGINEERED BUILDING STRUCTURE

- PEB frames are tapered and flanges and webs often have variable thickness.
- The frame geometry matches the shape of the internal stress diagram, thus minimizing material waste and reducing the total weight.
- Green Building Structure
Panels with both side metal facing acting as impermeable vapour barriers
- Avoids moisture coming in contact with insulation
- No deterioration of insulation
- Joints between panels sealed
- Moisture remains always over metal sheet
- Equilibrium situation leading to Energy Conservation
- CFC & HCFC free, zero ODP, cyclo Pentane blowing
- Length upto 12 mtr.
- Green Panels – 5 Points

Automatic Plant
- Environment friendly
- Contimat

Mechanical product handling

Continuous Spray of Polyurethane Foam

DISCONTINUOUS CAMLOCKS
LLOYD PANEL SYSTEM

- Strict Quality Control
- Inhouse Lab

LLOYD PANEL SYSTEM

THERMAL & LOAD CHARACTERISTICS OF PANEL

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>60</th>
<th>80</th>
<th>100</th>
<th>120</th>
<th>150</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>'U' Value</td>
<td>0.36</td>
<td>0.26</td>
<td>0.21</td>
<td>0.19</td>
<td>0.14</td>
<td>0.11</td>
</tr>
<tr>
<td>Panel Weight</td>
<td>Kg/m²</td>
<td>11.25</td>
<td>12.05</td>
<td>12.85</td>
<td>13.65</td>
<td>14.85</td>
</tr>
</tbody>
</table>

LLOYD PANEL SYSTEM

PREFAB SANDWICH PANELS

Properties of polyurethane foam

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DENSITY</td>
<td>40±2 kg/m³</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>2.1 kg/cm²</td>
</tr>
<tr>
<td>At 10% deformation</td>
<td></td>
</tr>
<tr>
<td>Tensile strength</td>
<td>3.7 kg/cm²</td>
</tr>
<tr>
<td>Bending strength</td>
<td>4.0 kg/cm²</td>
</tr>
<tr>
<td>Adhesion strength (Foam to steel)</td>
<td>2.9 kg/cm²</td>
</tr>
<tr>
<td>Dimensional stability (48hrs)</td>
<td></td>
</tr>
<tr>
<td>-25 DegC</td>
<td>0.1%</td>
</tr>
<tr>
<td>+38 DegC &amp; 90% RH</td>
<td>0.1%</td>
</tr>
<tr>
<td>+100 Deg.C</td>
<td>0.4%</td>
</tr>
<tr>
<td>Closed cell content</td>
<td>90-95%</td>
</tr>
<tr>
<td>Temperature range</td>
<td>-180Deg.C to +110 Deg.C</td>
</tr>
</tbody>
</table>

CFC & HCFC FREE, ZERO ODP, CYCLO Pentane

LLOYD PANEL SYSTEM

PREFAB SANDWICH PANELS

Properties of polyurethane foam

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal conductivity at 10 Deg. C</td>
<td>0.026k-cal/m-hr-deg.C or 0.023 W/mK</td>
</tr>
<tr>
<td>Fire resistance</td>
<td>&lt;125mm.</td>
</tr>
<tr>
<td>Horizontal extent of burn BS 4735</td>
<td></td>
</tr>
<tr>
<td>Self extinguishing ASTM D 1692</td>
<td>Passes</td>
</tr>
<tr>
<td>Not easily ignitable as per BS 476 pt.5 &amp; class 1 as per BS 476 pt.7 (for panel)</td>
<td></td>
</tr>
<tr>
<td>Water absorption</td>
<td>0.2% volume at 100% RH</td>
</tr>
<tr>
<td>Water vapour permeability</td>
<td>0.08-0.12 gms/hr m²</td>
</tr>
</tbody>
</table>

CFC & HCFC FREE, ZERO ODP, CYCLO Pentane

LOWEST THERMAL CONDUCTIVITY
GREEN POINTS : 5

MODERN PRACTICES IN COLD STORE CONSTRUCTION

Main features of Lloyd Panel System –

- A high strength to weight ratio, with significant savings in steel work and load bearing foundations, allowing large spans to be constructed with no intermediate columns.
- Dimensional stability.
- Maintenance-free surface.
- High thermal efficiency ensures low heat transmission, resulting in lower refrigeration load.
- No deterioration of thermal efficiency over time.
- Panels can be furnished in single jointless height / Length upto 12 mtrs. Partition wall can be easily erected as the panels are self supporting.
Main features of Lloyd Panel System –

- Panel system incorporates special “L” shaped single piece panels for CORNERS. This avoids wall to wall direct jointing – provides additional stability, strength, aesthetical appearance, easy house keeping etc.
- For additional reinforcement “U/L” shaped flashing are provided at wall to ceiling joints.
- Rain guard profile sheet over ceiling panels

MODERN PRACTICES IN COLD STORE CONSTRUCTION

INSTALLATION PROCEDURE

Structure, Panels

Ceiling, Wall, Floor Orientation

WALL – CEILING CONNECTION

1. Outer Corner Profile
2. Inner Corner Profile
3. Sealant
MODERN PRACTICES IN COLD STORE CONSTRUCTION

Covings

Special arrangement

MODERN COLD STORAGE

VERTICAL FIXING OF PANELS

MODERN COLD STORE

Lifting of panels for Wall

Panel External Wall

Max. single length 12M generally

MODERN COLD STORE

Panel External Wall

Max. single length 12M generally

MODERN COLD STORAGE

Panel External Wall

Max. single length 12M generally

PANEL FIXING ON FLOOR WITH CHANNEL
MODERN COLD STORE

1. PUF Panel
2. Steel Purlin

MODERN COLD STORAGE

INSIDE VIEW

MODERN COLD STORAGE

INSIDE VIEW

MODERN PRACTICES IN COLD STORE CONSTRUCTION

Panel Partitions

Multi Chambered Cold Stores

MODERN PRACTICES IN COLD STORE CONSTRUCTION

Wall Construction details with Panels

WALL PANELS ERECTED
MODERN PRACTICES IN COLD STORE CONSTRUCTION

Roof Construction details with Panels

Ceiling Panel

Panel to Hanger orientation

MODERN PRACTICES IN COLD STORE CONSTRUCTION

CEILING SUSPENSION SYSTEM

3. Sealant
7. PUR Injection
15. Purlin
16. Truss
17. Ø 10 Hanger Tiege
18. Adhesive Tape
19. Cover Profile
20. Suspension Profile

FIXING OF CEILING PANELS

MODERN PRACTICES IN COLD STORE CONSTRUCTION

Floor Construction details

TYP. FLOOR DETAIL

MODERN COLD STORAGE

FIXING OF CEILING PANELS

MODERN PRACTICES IN COLD STORE CONSTRUCTION

Ceiling Panel
MODERN PRACTICES IN COLD STORE CONSTRUCTION

Floor Construction details

WALL FLOOR CONNECTION

- Sealant
- L Profile
- Bottom Border Profile
- Plain Concrete For Slope
- Protective Concrete
- Reinforced Concrete
- Floor Water Insulation
- Floor Heat Insulation
- Lean Concrete

MODERN PRACTICES IN COLD STORE CONSTRUCTION

WALL FLOOR CONNECTION

- Inner Corner Profile
- L Profile
- Reinforced Concrete
- Floor Water Insulation
- Floor Heat Insulation
- Lean Concrete

MODERN COLD STORE

Rain Guard

Colour Coated GI Sheet

VARIETY OF DOORS

HINGE & SLIDING
SAFETY - FIRE SAFE PANELS
- Classified under Class-1 Construction
- Classified as Not Easily Ignitable according to BS: 476 Part-5
- Surface Spread of Flame Classification determined as Class-1 according to BS: 476 Part-7

Environment Friendly
- Zero ODP PUF
- CFC, HCFC Free Rigid Polyurethane Foam
- Steel finish

HYGIENE
- Panels does not allow growth of any Biological item
- Corners have flashings /covings to stop any dust deposition
- Panels are washable
MODERN COLD STORE

MODERN COLD STORAGE

MODERN PRACTICES IN COLD STORE CONSTRUCTION – CONTRACTING

MODERN PRACTICES IN COLD STORE CONSTRUCTION – CONTRACTING

MODERN PRACTICES IN COLD STORE CONSTRUCTION – CONTRACTING

MODERN PRACTICES IN COLD STORE CONSTRUCTION – CONTRACTING

INTERIOR

COMPLETED PROJECT
GREEN COLD STORAGE

PEB STRUCTURE, PANEL, DOOR
MULTI PRODUCT MULTI CHAMBERED COLD STORE

PEB STRUCTURE, PANEL, DOOR
MULTI PRODUCT MULTI CHAMBERED COLD STORE

RAFTER & PURLINS
MULTI PRODUCT MULTI CHAMBERED COLD STORE

RAFTER & PURLINS
MULTI PRODUCT MULTI CHAMBERED COLD STORE
MULTI CHAMBERED CORRIDOR

RACKING

PRODUCT STORAGE

FIXING OF HORIZONTAL PANEL FROM INSIDE CA STORAGE

PANEL ERECTION PROCEDURE HORIZONTAL FIXING TO COLUMNS FROM OUTSIDE

HORIZONTAL PANEL ERECTION PROCEDURE
MODERN COLD STORE FEATURES

- LARGE INTERIOR SPACE
- POTATO COLD STORAGE
  PROPER UTILIZATION OF SPACE
- CLEAN INTERIORS
- PROPER AIR FLOW
- CHILLED WATER INSULATED PIPES WITH PVC CLADDING
- COLD STORE OVER EXISTING RCC BUILDING COLD STORES

COLD STORAGE CONSTRUCTION

2009
COLD STORAGE CONSTRUCTION

PEB & Panels over RCC Building

COLD STORAGE CONSTRUCTION

Long Height Corridor

COLD STORAGE CONSTRUCTION

Corridor & Multi Level Doors

COLD STORAGE CONSTRUCTION

Flooring

COLD STORAGE CONSTRUCTION

Ceiling Panels
COLD STORAGE CONSTRUCTION

Ceiling Panels

Chilled Water Piping

Chilled Water Pipe Support

Chilled Water Pipe Insulation

Chilled Water Pipe Insulation

PRE-INSULATED PIPE
- Less labour intensive & fast construction technology.
- More interior space.

MODERN COLD STORE CONSTRUCTION
Panel Erection Inside Warehouse

MODERN COLD STORE CONSTRUCTION

CLEAN ROOM

MODERN PRACTICES IN COLD STORE FEATURES
Food Processing
Chambers made from PUF Panels

MODERN PRACTICES IN COLD STORE FEATURES
Food Processing
Chambers made from PUF Panels

COLLECTION CENTRE STORES
- Small stores
- Prefab Panels
- 5-7 degree temperature drop
- With or without cooling
- Exhaust fan
Field Store

TRANSPORTATION
REFRIGERATED VAN
TRANSPORTATION

REFRIGERATED VAN

STRUCTURE – FRAMEWORK - PANELS

INSULATED DOORS

REFRIGERATED VAN

RUBBER GASKET SEALING

RUBBER GASKET SEALING

REFRIGERATED VAN

PLASTIC CURTAIN

INTERIOR
COLD STORAGE CONSTRUCTION COST

I. CONVENTIONAL COLD STORE
CAPACITY : 5000 MT
a) Brick : 5 Lacs nos. @Rs.12/Brick = Rs.60 Lacs
b) 4-6" EPS + 0.5 / 0.6mm TCT = Rs.60 Lacs
   Colour coated GI Sheet
c) Total Cost : Rs. 10,000 – 12,000/MT

COLD STORAGE CONSTRUCTION COST

II. MODERN COLD STORE
CAPACITY : 5000 MT
a) Panels : Rs. 115-120 Lacs
b) Total Cost : Rs. 12,000 – 14,500/MT
   (PEB, Panels, Refrigeration, Civil, Racking, machinery etc.)

III. Difference : 20-25 %

COLD STORAGE CONSTRUCTION COST

IV. Almost same for conversion from Brick + Insulation to panels i.e. Rs.120 Lacs

V. Total cost for 7000 tons Cold Store with RCC Roof, RCC columns & Panels = Rs.675 Lacs (@9643/Ton (approx.))

COLD STORAGE CONSTRUCTION COST

CAPACITY : 7000 MT
RCC Roof, RCC columns & Panels
Civil : 250 Lacs
Panel : 115 Lacs
Land : 50 Lacs
Building : 30 Lacs
Racking : 50 Lacs
Lighting : 80 Lacs
Machinery : 100 Lacs
-------------------------------
675 Lacs
--------------------------

TECHNICAL STANDARDS AND PROTOCOL FOR THE COLD CHAIN IN INDIA

National Horticulture Board
(Department of Agriculture & Cooperation
Ministry of Agriculture, Govt. of India)
85, Institutional Area, Sector-18
Gurgaon -122015 (Haryana)
OPTION-1:
Typical 5000 MT Multi Commodity Cold Store with provision of rapid room cooling and palletized storage, suitable for long / medium term storage of Fruit and Vegetables.

OPTION-2:
Typical Multi Commodity Cold Store with provision of separate pre-cooling rooms and high humidity cold stores.

- Cold Chamber : 250 - 1250 MT – 4 nos.
- Multi Commodity chambers : 30 - 1250 MT
- Pre-cooling chamber : 30 - 150 MT
CONSTRUCTION FEATURES

Super Structure Foundation: As per BIS Standards
Cold Store Building: RCC OR steel structure / PEB as per IS : 875

Cold Chamber:
Walls - 1. 230mm brick wall with plaster on both sides, vapour barrier insulation and profiled pre-coated GS sheet
2. Pre-fab steel structural frame work with insulated panel boards

CONSTRUCTION FEATURES

Cold Chamber:  
Roof - 1. RCC slab with waterproofing, proper sloping and mosaic finish.
2. Truss roof with pre-coated GS sheet with FRP sheet provision for natural lighting and turbo ventilators or alternatively insulated roofing panels. There should be provision for fixing insulated panels from the trusses to act as False Ceiling. FRP sheet for natural lighting

Floor - Base concrete with insulation & RCC finish.

STEEL / PRE-ENGINEERED CONSTRUCTION

- Structure as per ASTM / BIS Standards
- Wall, Ceiling & partition with insulated panels of PUF, 1-1.2 mtr. Wide & length max. 12 mtr., 80mm thick.
- Single piece from floor to ceiling
- Held by fasteners
- Joints sealed with Silicon Sealant

ANTE ROOM

- At least one Ante room
- Sorting, grading area
- Temperature range 20 - 24 deg.C
- Mechanized sorting, grading, washing & packing
- Palletization & Strapping Facility
- Pallet Jack & Fork Life
- Bins, Crates, Pallets and Racks
- Strip curtains for cold rooms and air curtains for external outlets / inlets
- Rodent proof civil structure and proper drainage of water to be ensured
- Rooms for machines, Electrical etc.

Insulation Thickness

<table>
<thead>
<tr>
<th>Type of Insulation</th>
<th>Material</th>
<th>External U Value = 0.27 W/mK</th>
<th>Wall</th>
<th>Ceiling</th>
<th>Roof</th>
<th>Floor</th>
<th>U Value = 0.20 W/mK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Density (kg/m³)</td>
<td>K at 10°C (W/mK)</td>
<td>Thickness (mm)</td>
<td>Thickness (mm)</td>
<td>Thickness (mm)</td>
<td>Thickness (mm)</td>
</tr>
<tr>
<td>EPS</td>
<td></td>
<td>15</td>
<td>0.039</td>
<td>100</td>
<td>75</td>
<td>100</td>
<td>125</td>
</tr>
<tr>
<td>PUF</td>
<td></td>
<td>32</td>
<td>0.033</td>
<td>100</td>
<td>50</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>XPS</td>
<td></td>
<td>30-35</td>
<td>0.023</td>
<td>100</td>
<td>50</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Phenolic Foam***</td>
<td></td>
<td>20</td>
<td>0.028</td>
<td>100</td>
<td>50</td>
<td>125</td>
<td>100</td>
</tr>
<tr>
<td>Phenolic Foam***</td>
<td></td>
<td>20</td>
<td>0.028</td>
<td>100</td>
<td>50</td>
<td>125</td>
<td>100</td>
</tr>
<tr>
<td>Mineralwool***</td>
<td></td>
<td>48</td>
<td>0.033</td>
<td>125</td>
<td>50</td>
<td>125</td>
<td>100</td>
</tr>
<tr>
<td>Bonded Fibre Glass</td>
<td></td>
<td>32</td>
<td>0.033</td>
<td>125</td>
<td>50</td>
<td>125</td>
<td>100</td>
</tr>
<tr>
<td>Glass wool panel**</td>
<td></td>
<td>60</td>
<td>0.033</td>
<td>80</td>
<td>60</td>
<td>80</td>
<td>80</td>
</tr>
</tbody>
</table>

***Recommended only with vapour barrier and metal or FRP cladding min. 0.5mm TCT
**Recommended in conformance to ISO/FDIS 4898:2008(E) for properties of EPS used for thermal insulation of buildings, Categories II, III & IV only.

ANCILLARY MATERIALS

- Vapour barrier e.g. aluminium foil, polythene sheet, with bitumen / cold mastic adhesives
- Teakwood batten pegs, tees etc.
- G.S. Sheet runners (avoid wooden batten runners)
- Cladding of profiled / pre-coated G.S. Sheets 0.5 / 0.6mm thick / Fibre – glass sheets of suitable thickness
CONSTRUCTION FEATURES

FOR CONVENTIONAL INSULATION

WALL & CEILING

- Primer coat followed by two layers of bitumen
- Fixing aluminium foil min. 50 microns
- Fixing wooden pegs at suitable intervals
- Fixing two layers of insulation with staggered joints
- Fixing G.S. Sheet runners over the pegs in longitudinal & lateral directions
- Fixing profiled & pre-coated G.S. sheet 0.5 / 0.6mm thick over the runners with proper finishing of joints. Alternatively FRP sheets can be used

CONSTRUCTION FEATURES

FOR INSULATED PANEL STRUCTURE

WALLS & CEILING

- Perimeter of the plinth to be in level for panel installation
- Panels to have cam lock or tongue & groove joints
- Sheet metal flashing to be provided on all concrete, curbing to be provided on wall – floor joints
- Horizontal tie bracings to be provided between vertical wall panels & external columns, to take care of wind loads
- Adequate numbers of pressure relief ports to be provided on all chambers with electrical connection
- Insulated doors shall be suitable for panel mounting

CONSTRUCTION FEATURES

FOR CONVENTIONAL INSULATION

FLOOR

- Laying of polythene sheet, min. 250 microns as vapour barrier
- Fixing insulation slabs in two layers with bitumen as adhesive for the first layer
- Covering with tar felt
- Laying PCC / tremix of 75mm / 100mm thickness.

NHB OPERATIONAL GUIDELINES

CAPITAL SUBSIDY FOR NEW CONSTRUCTION / EXPANSION / MODERNIZATION OF COLD STORAGES

Components : Cold Stores, CA, MA, Pre-cooling Units
Capacity : Up to 5000 MT
Amount : 40% of capital project cost in general areas
55% in case of Hilly & scheduled areas

For Storage capacity of 5000 MT

GENERAL CONDITION

1. Multi Chamber Cold Storages with Mezzanine floors of RCC or wooden structure, without precooling, 0-16°C or above, RH 80-95%, 65-70% for Onion & Garlic, min. 2 chambers, standard insulation, cooling system, safety devices.

Construction cost basis
Rs. 6000 per MT

GENERAL CONDITION

2. Multi Chambered & Multi Product Cold Storage, without precooling system, -2 to 16°C, RH 80-95% general P&V, 85-70% for Onion & Garlic, energy saving devices, heat exchanger with CO₂ control, control of micro organism, mechanical handling – fork lifts, safety devices.

a) Civil / Prefab engg. structure, insulation, cooling as per standards excluding mezzanine
Construction cost basis
Rs. 7000 per MT

b) Civil / prefab engg. structure, insulation, cooling as per standards excluding mezzanine, having pack house facilities (sorting, grading, wax in, packing)
Construction cost basis
Rs. 8000 per MT
**NHB OPERATIONAL GUIDELINES**

**GENERAL CONDITION**

3. Modernization of Cold Stores
   a) Upgradation of Thermal Insulation
   b) Upgradation of cooling system, safety devices, electricals

Rs.1000/MT for Multi chambered Cold Stores with mezzanine floor

Rs.2000/MT for Multi chambered multi product with prefab engg. and with or without pack house

**THERMAL INSULATION**

Procedure - As per IS : 661

**Materials:**
- a) Expanded Polystyrene
- b) Rigid Polyurethane Foam
- c) Rigid Phenolic Foam
- d) Mineralwool / Glasswool
- e) Extruded Polystyrene

Thermal Insulation for Refrigerated Piping:
- EPS, PUF, Nitrile Rubber

**Vapour Barrier:**
- Aluminium Foil, Polythene Sheet
  Bitumen Cold Adhesive Mastic for insulated panel structure.
  Pre-fabricated panels with cam lock or Tongue & Groove joints.

**THERMAL INSULATION MATERIALS**

- Expanded Polystyrene
- Polyurethane / Polyisocyanurate Foam
- Fibrous material
- Polyurethane sandwich Panels

**IS : 661**

**Thermal Insulation of Cold Storage – Code of Practice**

(4th Revision of IS : 661))

(ICS No.27.220; 91.120.10)
IMPORTANT CHARACTERISTIC OF A COLD STORAGE INSULATION

a) Low Thermal Conductivity (K)
b) Lower Thermal Diffusivity (d)
c) High Thermal Resistivity (R)
d) Stability at low temperature

IN-SITU APPLICATION

Insulation of Concrete / Masonry Walls finished with Plaster.

- Cleaning of the surface
- Application of primer and vapour barrier layer
- Fixing of wooden batten and 40mm wide and equal to insulation thickness suitably placed,
- Providing insulation in multi layer (single layer 50mm with joints staggered)
- Application of wire netting and fixed with galvanized U nails
- Application of cement plaster
- Floor insulation shall be with bituminous water proofing, insulation slab, bituminous kraft paper and concrete.

PANEL APPLICATION

- Main structure of Steel / RCC frame or Brick
- PU Panels are directly mechanically fastened to the Steel or RCC structure frame
- Incase of brick wall, one side paper laminated panels to be mechanically fastened.
- Panel joints sealed with silicon sealant.
- Floor insulation with PUF slabs.
- Ceiling insulation – PU Panel shall be placed on insulated T-beams hung from trusses.

Fixing detail of PU Panel on Wall & Partition Wall
### Physical Properties of Insulating Materials

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Density, kg/m³</th>
<th>Thermal Conductivity, W/(m·K)</th>
<th>Water Absorption, %</th>
<th>Storage Temp. (Deg C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>PUF/PIR</td>
<td>0.023</td>
<td>0.002</td>
<td>0.1</td>
<td>-10 to 15</td>
</tr>
<tr>
<td>ii</td>
<td>Phenolic</td>
<td>0.026</td>
<td>0.005</td>
<td>0.1</td>
<td>+2 to 10</td>
</tr>
<tr>
<td>iii</td>
<td>Glasswool</td>
<td>0.037</td>
<td>0.012</td>
<td>0.2</td>
<td>15 to 25</td>
</tr>
<tr>
<td>iv</td>
<td>Rockwool</td>
<td>0.033</td>
<td>0.010</td>
<td>0.2</td>
<td>15 to 35</td>
</tr>
<tr>
<td>v</td>
<td>Polystyrene</td>
<td>0.038</td>
<td>0.011</td>
<td>0.3</td>
<td>15 to 25</td>
</tr>
</tbody>
</table>

### Insulation Thickness for Different Materials (in mm)

#### Storage Temp. Range:
- For Design Ambient Temperature of 35°C and 70-90 Percent Relative Humidity

#### Thickness for Intermediate Wall

<table>
<thead>
<tr>
<th>Storage Temp. Range</th>
<th>PUF/PIR</th>
<th>PES</th>
<th>Rock wool</th>
<th>Glass wool</th>
<th>PUF/PIR Panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10 to -5</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>0 to 10</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>-5 to -1</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>5 to 10</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>10 to 15</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>15 to 20</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>20 to 25</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>25 to 30</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>30 to 35</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>35 to 40</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>40 to 45</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>45 to 50</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>50 to 55</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>55 to 60</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>60 to 65</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>65 to 70</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>70 to 75</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>75 to 80</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>80 to 85</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>85 to 90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>90 to 95</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>95 to 100</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
</tbody>
</table>

#### Thickness for Roof

<table>
<thead>
<tr>
<th>Storage Temp. Range</th>
<th>PUF/PIR</th>
<th>PES</th>
<th>Rock wool</th>
<th>Glass wool</th>
<th>PUF/PIR Panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30 to -20</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>-20 to -10</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>-10 to -0</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>0 to 5</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>5 to 10</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>10 to 15</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>15 to 20</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>20 to 25</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>25 to 30</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>30 to 35</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>35 to 40</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>40 to 45</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>45 to 50</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>50 to 55</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>55 to 60</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>60 to 65</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>65 to 70</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>70 to 75</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>75 to 80</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>80 to 85</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>85 to 90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>90 to 95</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>95 to 100</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
</tbody>
</table>

**Note:** The tables and figures are from IS : 661 and IS : 12436, providing detailed specifications and calculations for insulation materials and their applications in various construction contexts.
**IS : 661**

**ANNEX B (2)**
(Class 4.2.1)

Thermal & Load Characteristics of PU Panels

<table>
<thead>
<tr>
<th>Thickness</th>
<th>60°C</th>
<th>40°C</th>
<th>20°C</th>
<th>10°C</th>
<th>0°C</th>
<th>-10°C</th>
<th>-20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel</td>
<td>Kg/m²</td>
<td>Kg/m²</td>
<td>Kg/m²</td>
<td>Kg/m²</td>
<td>Kg/m²</td>
<td>Kg/m²</td>
<td>Kg/m²</td>
</tr>
<tr>
<td>PU F/PIR</td>
<td>11.65</td>
<td>10.05</td>
<td>12.05</td>
<td>13.45</td>
<td>15.95</td>
<td>16.05</td>
<td></td>
</tr>
<tr>
<td>Phenolic</td>
<td>11.65</td>
<td>10.05</td>
<td>12.05</td>
<td>13.45</td>
<td>15.95</td>
<td>16.05</td>
<td></td>
</tr>
<tr>
<td>Foam</td>
<td>11.65</td>
<td>10.05</td>
<td>12.05</td>
<td>13.45</td>
<td>15.95</td>
<td>16.05</td>
<td></td>
</tr>
<tr>
<td>EPS</td>
<td>11.65</td>
<td>10.05</td>
<td>12.05</td>
<td>13.45</td>
<td>15.95</td>
<td>16.05</td>
<td></td>
</tr>
<tr>
<td>Rock Wool</td>
<td>11.65</td>
<td>10.05</td>
<td>12.05</td>
<td>13.45</td>
<td>15.95</td>
<td>16.05</td>
<td></td>
</tr>
<tr>
<td>Glass Wool</td>
<td>11.65</td>
<td>10.05</td>
<td>12.05</td>
<td>13.45</td>
<td>15.95</td>
<td>16.05</td>
<td></td>
</tr>
</tbody>
</table>

**IS : 661**

**Recommended “R & U” Value for cold storage structure**

<table>
<thead>
<tr>
<th>Storage Temp. Range (°C)</th>
<th>R Value (m²K/W)</th>
<th>U Value (W/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30 to -20</td>
<td>5.88</td>
<td>0.17</td>
</tr>
<tr>
<td>-20 to -15</td>
<td>4.76</td>
<td>0.21</td>
</tr>
<tr>
<td>-15 to -4</td>
<td>4.34</td>
<td>0.23</td>
</tr>
<tr>
<td>-4 to +2</td>
<td>3.70</td>
<td>0.27</td>
</tr>
<tr>
<td>+2 to 10</td>
<td>2.85</td>
<td>0.35</td>
</tr>
<tr>
<td>10 to 16</td>
<td>2.12</td>
<td>0.47</td>
</tr>
<tr>
<td>16 and above</td>
<td>0.78</td>
<td>1.28</td>
</tr>
</tbody>
</table>

**MODERN PRACTICES IN COLD STORE CONSTRUCTION**

**CASE STUDY (For Potato Storage)**

**CONVENTIONAL COLD STORAGE DESIGN**
Vs.

**MODERN COLD STORAGE DESIGN**

Storage Capacity : 6000 MT

Size : 105’ (32M) x 105’(32M) x 60’ (18M) (H)
**MODERN PRACTICES IN COLD STORE CONSTRUCTION**

**CONVENTIONAL STORAGE**

**Ceiling Design**
Ceiling is made up in a similar manner, with EPS being 100 mm or 4” in thickness (in case of RCC Slab as roof).

**Floor Design**
Floor is insulated with 60mm EPS, after tar felting and finished with Lean Concrete (PCC) 3” (75mm).

---

**THEORETICAL HEAT GAIN FOR CONVENTIONAL CONSTRUCTION**

Considering the Thermal Conductivity value for Polystyrene Foam (EPS) as 0.036 W/mK in order to allow for aging and imperfections during application for an ambient of 40-45 deg.C and operation at 4 to 6 deg.C.

---

**MODERN PRACTICES IN COLD STORE CONSTRUCTION**

**CONVENTIONAL STORAGE**

**Thermal Transmission Values**
- **Q Wall** = 12.26 W/m2
- **Q Ceiling** = 8.98 W/m2

Considering a 6000MT Potato Cold Store
- **Dimension** 105’ (32M) x 105’(32M) x 60’(18M) (H)
- **Total Area**
  - Wall – 1152 m2, Ceiling -1024m2, Floor – 1024 m2.

**Thermal Transmission Value**
- **Q Total (Theoretical)** = 24 KW

---

**MODERN COLD STORES**

- **Wall** = 80mm PUF Panel
- **Ceiling** = 100mm PUF Panel
- **Floor** = 60mm EPS Slabs finished with lean concrete

12-15% reduction in heat gain.

Initially Energy Savings Rs.13000 per month or Rs.1.60 Lacs per annum.
Thereafter Rs.43000 per month or Rs.5-6 Lacs per annum.

---

**EXISTING COLD STORES**

- Civil Structure / Building Sound Construction
- Insulation damaged
- Reap of Insulation

**REVAMP PROCEDURE**
- Insulation can be replaced by – Pre-fab Polyurethane Panels

---

**MODERN PRACTICES IN COLD STORE CONSTRUCTION**

**CONVENTIONAL STORAGE**

**Ceiling Design**
Ceiling is made up in a similar manner, with EPS being 100 mm or 4” in thickness (in case of RCC Slab as roof).

**Floor Design**
Floor is insulated with 60mm EPS, after tar felting and finished with Lean Concrete (PCC) 3” (75mm).
EXISTING COLD STORES

- Removal of old insulation & plastering of surface.
- Prefab Polyurethane Panels with facing side metal finish and inner side paper or Aluminium foil finish.
- Panels to be directly fixed to the walls with self drilling fasteners.
- Sealing of Panel joints with Silicon Sealant.

REVAMPING OF EXISTING STORES

Replacement of moisture soaked Insulation

> Fixing prefab panels with one side metal facing and paper facing on the walls.

CHATRAKARAN POTATO COLD STORAGE, INDORE (MP)

FIRST MODERN POTATO COLD STORE 1997

SANGHA CHAITANYA COLD STORAGE, KHAMMAM (AP)

NEETHI COLD STORAGE, HYDERABAD

SAFAL COLD STORAGE COMPLEX, BANGALORE
HINDUSTAN AGRO COOPERATION LTD.

Agro Irradiation Cold Storage at Rahuri, Ahmednagar
25000 MT

PRAGATI COLD STORAGE, KUNDLI

2010

MODERN COLD STORE

Future Trend for Construction

MODERN COLD CHAIN MANAGEMENT INCREASING LIFE SPAN OF FRESH PRODUCE FROM FARM TO FORK

THE PRODUCER

THE CONSUMER

The Repaired Pipeline

THE NECESSITY (Grower’s perspective)
Good cold chain practices

FINALLY

THE NEED (Customer’s perspective)
Fresh & Safe Produce

PRESENTER

SAVE ENERGY, SAVE EARTH
LLOYD INSULATIONS (INDIA) LIMITED

Pay heed to the calls, before another moment falls

Everyone thinks of changing the world, but no one thinks of changing himself.

Leo Tolstoy