Dry Ice Expanded Tobacco

Airco DIET was one of the originally inventors of the DIET process and the first Airco DIET plants were sold in 1979. Now 30 years later close to 50 Airco DIET plants have been installed around the globe!

The DIET Process

Dry Ice Expanded Tobacco improves smoking quality and is the most effective tool for tar and nicotine reduction in cigarettes using tobacco lamina. DIET also reduces the bulk density of the cigarette blend which significantly reduces the cost of manufacturing. The DIET Process uses the unique thermal and physical properties of carbon dioxide to expand tobacco. Cut tobacco is submerged in liquid carbon dioxide under high pressure conditions in a pressure vessel known as an impregnator. After a brief soak period, the liquid carbon dioxide is drained to the process tank and used again. Carbon dioxide gas remaining in the impregnation vessel is recovered by compression and condensation and returned to the process tank to be used again. When the pressure in the impregnator is reduced to atmospheric, the residual liquid carbon dioxide in the tobacco cells turns to dry ice. The frozen tobacco is fed to a declumper to produce a flowing constituent that is metered into the re-circulating hot gasses of the sublimator tower. When heated, the frozen carbon dioxide in the tobacco cells sublimes and increases in volume more than 100,000 times. The resulting internal pressures inflate the tobacco cells to provide a volume increase. The expanded tobacco is removed from the sublimator by a tangential separator and reordered to restore the moisture to target. A net volume increase of about 100% to 140% at target moisture is realized with the DIET process.

Airco DIET’s continues technical development program provides process innovations for economic production of high quality expanded tobacco with minimal Tobacco degradation, high preservation of particle size and low dust generation. Plant safety is given the highest priority! Airco DIET feature intensive training of operators, supervisors and engineers. All equipment is designed with the best possible safeguard and all potential high risk areas are hard wired interlocked. In addition a highly sophisticated and well proven PLC programming is constantly monitoring the complete DIET plant.
DIET Process in detail

The following description applies to Airco DIET’s Standard 2400 kg/hr DIET (Dry Ice Expanded Tobacco). (It is however also identical to the process for the smaller plants except for the double A & B equipment.)

It includes five sections:

I. INTRODUCTION
II. INFEED SYSTEM
III. COLD END SYSTEM
IV. HOT END SYSTEM
V. REORDERING

I. INTRODUCTION

A. Dry Ice Expanded Tobacco

The Dry Ice Expanded Tobacco (DIET) process treats cut filler by impregnation of the cell structure with liquid carbon dioxide under pressure. Excess liquid and gaseous carbon dioxide are recovered for reuse by staged pressure release. The carbon dioxide within the tobacco solidifies to dry ice. The impregnated tobacco is then rapidly expanded in a stream of hot gas and, is reordered to acceptable moisture for required for the final product. The DIET product may be packaged or stored.

The DIET process uses liquid carbon dioxide to achieve approximately 100-140% expansion of cut filler, thus, generating extra filling power in cigarette making. Expanded tobacco is a key factor in the design of low yield cigarettes and the increased filling power significantly reduces unit production cost in cigarettes.

DIET processing is a parallel operation that is easily coordinated with other production steps. DIET treated tobacco is blended back into your line after reordering at any convenient step in the process. DIET use allows custom production of cigarettes with specific quality characteristics.
B. Airco DIET Production Line

The Airco DIET Line proposed is highly automated. It includes an Infeed System, Cold End System, Hot End System and Controls & Instrumentation. From the start, the Infeed System handles the cut filler tobacco from the Primary Line and prepares the tobacco for the Cold End System. After processing the cut filler tobacco with the Cold End System, CO₂ or dry ice impregnated tobacco is formed. This impregnated tobacco is then introduced into the Hot End System for rapid tobacco expansion. At the end of the Hot End System, with the proper moisture recovery, >100% expanded tobacco product is discharged and ready to be used or formulated for cigarette making.

A sophisticated and well-proven Controls & Instrumentation package is selected for the DIET Line. It is fully integrated into various parts of the plant. It allows the DIET Line to be highly automated, user-friendly, easy-to-diagnose and safe.

There are four diagrams attached at the end of this section to assist one while reading this proposal:

1. Expanded Tobacco Flow Block Diagram
2. Tobacco Process Flow Diagram
3. DIET Cold End Process Flow Diagram
4. DIET Hot End Process Flow Diagram

In Diagram (1), the flow of the tobacco is described in easy to follow blocks. Diagram (2) also depicts the tobacco flow while illustrating it with the DIET equipment. Diagram (3) depicts the Cold End CO₂ flow and the Recovery Loop, and diagram (4) shows the Hot End System with the Process Heater / Heat Exchangers.
Tobacco Flow Diagram
Double Imprenator DIET Plant

Silo ➔ Pinfeeder ➔ Weighing Conveyor ➔ Holding Conveyor ➔ Shuttle Conveyor

Choke Tube ➔ Active Storage Bin ➔ Declumper A ➔ Transfer Chute A ➔ Impregnator A

Declumper B ➔ Transfer Chute B ➔ Impregnator B

Metering Conveyor ➔ Inlet Rotary Airlock ➔ Sublimator ➔ Tangential Separator ➔ Outlet Rotary Valve

Belt Conveyor ➔ Moisture Meter ➔ Reordering Cylinder ➔ Belt Conveyor ➔ Vibrating conveyors

Silo
Tobacco Process Flow Diagram

Airco DIET

Cold End Equipment

Hot End Equipment

Tobacco from Storage Bin

Transfer Chute

Tobacco

Impregnators

Declumpers

Storage Bin

Metering Conveyor

Inlet Rotary Valve

Venturi

TC-40

V-23A

V-23B

DC-41

TC-44

SL-50

MC-45

RV-46

Hot End Equipment

Cold End Equipment

Expanded Tobacco to Boxing Station

Outlet Rotary Valve

Cooling Conveyors

Re-Ordering Cylinder

BC-30

Shuttle Conveyor

AB-44

V-23A

V-23B

MC-45

RC-80

BC-40

DC-41

RV-52

VC-71

BC-72

BC-73

TC-40

DC-41

RV-46
II. INFEED SYSTEM

A. Process Description

The Primary Line supplies cut lamina to the Airco DIET Line. The capacity of the Primary Line must be sized, in such that the Infeed System will have consistent and sufficient cut tobacco when running the DIET Line. The Infeed System is the equipment components after the Primary Line and before the Cold End System, which is described in the next section. The Infeed System handles cut tobacco prior to expansion in the DIET Line and creates the tobacco batching for the Cold End. The equipment components are Pin Feeder (PC-29), Weigh Conveyor (WC-30), transferring Belt Conveyor (BC-31), dual speed Belt Staging Conveyor (BC-32) and the Pivoting Shuttle Band Conveyor (BC-33).

The Primary Line will prepare freshly cut tobacco between 20% ~ 26% of moisture. The tobacco density estimates tend to be around 160 kg/m³. This tobacco is fed to Airco's Infeed System. This Infeed System starts with a Pin Feeder (PC-29) allowing some freshly cut tobacco to be accumulated. Then, there will be an Infeed System control signal coming approximately every 7.5 minutes from the downstream Cold End System when a demand for tobacco impregnation is requested.

When the DIET Cold End Operator is ready to accept a batch of cut tobacco for one of the two Impregnator, V23A or V-23B, he/she simply presses a key "Process Continue" on an Operator Interface (OI) to activate an automatic V-23 tobacco loading procedure.

At this time, the Impregnator bottom lid is closed and the top lid is fully opened. The Shuttle Band Conveyor (BC-33) will automatically pivot itself towards the designated Impregnator and extend from its "home position" onto the top of the Impregnator (V-23). After BC-33 is fully extended, a telescopic chute will be let down to minimize tobacco dust from discharging outside the Impregnator. BC-33 conveyor belt will start. Sequentially Belt Staging Conveyor (BC-32), which is now loaded with cut tobacco will advance at a high speed and dump the load into the Shuttle Band Conveyor (BC-33), which will then feed the entire batch of tobacco into the Impregnator (V-23). After the Staging Belt Conveyor (BC-32) is empty it continues to run empty for a few more seconds, then it automatically stops. Then, the Shuttle Band Conveyor (BC-33) will reverse its function by stopping the belt, lifting the telescopic chute and retracting back to its "home position".

Now that the Staging Belt Conveyor (BC-32) is empty, it must be refilled with cut tobacco and be ready for the next cycle. Via the PLC, BC-32 sends signal to BC-31 and the Weigh Conveyor (WC-30) to startup the refill process. The Weigh Conveyor (WC-30) will activate and request to be fed. The Pin Feeder (PC-29) then will start and allow tobacco to be fed onto the Weigh Conveyor. A preset amount, around 350 kg/batch, of cut tobacco will be measured by WC-30 and to be loaded, via the transferring Belt Conveyor BC-31, onto the Belt Staging Conveyors BC-32, which is running at a slow speed mode.

When the required amount of tobacco is accumulated or batched on BC-32, BC-31 and WC-30 will stop, thus, stopping PC-29 from feeding onto WC-30. At this moment, BC-32 will send a signal to the OI to announce that "Tobacco is Ready" again for the next batch. Under normal operating condition, the operator will select to alternate the use of Impregnators in order to meet the production capacity. BC-33 will pivot the opposite direction and load the tobacco into the second Impregnator. Therefore, the tobacco loading activity must occur in 6-minute cycle time. Cold End System will process the tobacco from that point onwards.
B. **Equipment Description**

1. **Pin Feeder PC-29**

   The Pin Feeder PC-29 receives freshly cut filler tobacco from the conveyor with 20% ~ 26% of moisture. It will be designed for de-lamination with a minimum of degradation. The unit will be sized sufficiently to queue and supply cut tobacco to the Weigh Conveyor WC-30, which requires 350 kg every batch within a 6-minute cycle loading time.

2. **Weigh Conveyor WC-30**

   When cut filler tobacco is demanded by the Belt Staging Conveyors (BC-32), the Weigh Conveyor receives cut filler tobacco from the Pin Feeder PC-29. WC-30 weighs and totalizes the amount of tobacco while the tobacco is passing through its weighing rollers. When the set totalized batch weight is reached, WC-30 will stop the conveyor belt and stop the Pin Feeder from feeding. It will send the batch weight data to the DIET Operator Interface (OIs).

3. **Belt Conveyor BC-31**

   The Belt Conveyor BC-31 receives cut filler tobacco from Weigh Conveyor (WC-30), then transfer and discharge the tobacco onto the Belt Staging Conveyor (BC-32).

4. **Belt Staging Conveyor BC-32**

   The Belt Staging Conveyor BC-32 receives cut filler tobacco from Belt Conveyor (BC-31) and accumulate or batch the tobacco in 6 minutes on its belt. Then it discharges the tobacco onto the Shuttle Band Conveyor (BC-33) when “load tobacco” request is initiated by the DIET Operator via the Operator Interface (OI). It is capable of two speeds, a staging-slow speed and a loading-high speed.

5. **Pivoting Shuttle Band Conveyor BC-33**

   One “slider bed” type Pivoting Shuttle Band Conveyor BC-33 is supplied with a telescopic chute mounted at the discharge end. Since this conveyor is mounted on a pivoting mechanism, it is able to provide tobacco loading from the Belt Staging Conveyor BC-32 into two Impregnators, V-23A or V-23B, in an alternating fashion.

   When the operator requests for tobacco to be loaded into a designated Impregnator, the Pivoting Shuttle Band Conveyor will pivot horizontally and line up with the centerline of the designated Impregnator. The Impregnator will be in its ready to load position with the
bottom lid closed and the top lid open, the Shuttle Band Conveyor mounted on a powered trolley, extends and positions itself over the Impregnator. The telescopic chute then lowers into the impregnator.

When the telescopic chute is fully extended, the conveyor belts starts to run and the tobacco is discharging into the Impregnator V-23. BC-33’s telescopic chute retracts when the loading is completed and BC-33 returns to the “home position” clearing of the Impregnator lid.

III. COLD END SYSTEM

A. Process Description

Immediately following the Infeed System is the Cold End System. The Cold End process consists of two phases, (1) Impregnation of cut tobacco with liquid CO₂, and (2) Recovery of CO₂ from the impregnation process. Also, (3) Liquid CO₂ Storage, which is part of the Cold End equipment, is briefly described in this section.

1. Impregnation

Tobacco Impregnation is a batch process performed in the Impregnator (V-23), a vertical pressure vessel with hinged top and bottom lids. The impregnation process involves the use of CO₂ at a pressure of 30 Bar(g) and an impregnation cycle time, including the loading and, finally, unloading of the Impregnator (V-23) with cut filler tobacco, not to exceed 15 minutes.

In 2,280 kg/hr DIET Production Line, some Cold End equipment is doubled so that capacity requirement can be met with consideration of safety, operability, space constrain and economics. In the Cold End System, under Impregnation, there are two Impregnators (V-23A & V-23B), two Transfer Chutes (TC-40A & TC-40B) and two Declumpers (DC-41A & DC-41B). The “Stream A” equipment, i.e. V-23A – TC-40 A – DC-40A, function identically to “Stream B”, and they are used in an alternating fashion with a 7.5-minute off-phase.

Impregnation At the start of the cycle, the Impregnator lids are positioned as required for loading tobacco, with the top lid open and the bottom lid closed. Prior to loading, the tobacco is weighed to insure proper batch size, and then held on a batch conveyor. The batch conveyor feeds the tobacco onto the Shuttle Band Conveyor (BC-33) during the loading step. The Shuttle Band Conveyor (BC-33) equipped with a telescopic chute indexes over the Impregnator (V-23) and 350 kg of cut tobacco at 20% ~ 26% moisture is loaded into the Impregnator (V-23). The tobacco fills approximately 70% of the shell height of the Impregnator (V-23). Once the Impregnator (V-23) is filled with tobacco, the top lid is closed and locked. The top and bottom lid seals are then pressurized to allow full pressurization of V-23.
To remove air, which would have an adverse affect on CO₂ recovery, the Impregnator (V-23) is purged with CO₂ gas from the High Pressure Recovery Tank (T-10). Once approximately three volumes of purge gas have passed through the Impregnator (V-23), the atmospheric vent valve is closed allowing the Impregnator (V-23) pressure to be equalized with T-10. The valves between the Impregnator (V-23) and T-10 are closed and the valves between the Impregnator (V-23) and the Pressurization Tank (V-19) are opened. When V-23 pressure equalizes to the Process Tank (V-20), the V-23 / V-19 passage is closed and the valves between V-23 and V-20 are opened. The impregnator (V-23) is now ready to be filled with liquid CO₂.

The CO₂ gas, in the Impregnator (V-23), is then displaced by some of the liquid CO₂ accumulated in the Process Tank (V-20) via the Process Pump (P-22). The Impregnator (V-23) is filled to 80% of its shell height, completely immersing the tobacco. After the tobacco is briefly soaked, the excess CO₂ liquid is drained back to the Process Tank (V-20). Once the CO₂ liquid is recovered, the Impregnator (V-23) is ready to be de-pressurized and the CO₂ gas recovered.

The CO₂ gas recovery and de-pressurization occurs in two stages. The Impregnator (V-23) is vented to the High Pressure Recovery Tank (T-10) in the first stage and then to the Low Pressure Recovery Tank (T-08) in the second stage. Any remaining low pressure CO₂ is then vented to the atmosphere.

When the Impregnator (V-23) has achieved atmospheric pressure, the bottom lid is opened and the tobacco is discharged through a Transfer Chute to the Declumper (DC-41) and then to the Active Storage Bin (AB-44) where a buffer of impregnated tobacco is stored.

This process requires a cycle time of 15 minutes. Since there is another Impregnator running at a 7.5-minute off-phase, it means that there is a batch of impregnated tobacco being discharged every 7.5 minutes in the 2,280 kg/hr DIET Production Line.

**Impregnator Discharge and Declumping**

Once the impregnation process is completed, the bottom lid of the Impregnator opens and the batch of CO₂ impregnated cut tobacco is discharged by gravity into the Transfer Chute which directs the batch of frozen tobacco, now consisting of clumps of tobacco loosely bound by solid CO₂, to the Declumper (DC-41). This process occurs every 15 minutes for each Impregnator.

The tobacco is now frozen at a temperature of -79°C and contains approximately 8% solid CO₂. The Transfer Chute encloses the bottom portion of the Impregnator and directs the tobacco flow to the Declumper (DC-41). The Transfer Chute also contains the CO₂ vapor and tobacco dust generated when the frozen batch of tobacco is discharged from the Impregnator. Provision is made to connect an exhaust fan and ducting to the Transfer Chute to facilitate the removal of any residual CO₂ vapor.

The Declumper contains a series of counter-rotating shafts with pins mounted in a radial direction. The pins break-up any clumps in the batch so that the tobacco can be conveyed as a free flowing mass. The tobacco passes through the Declumper in approximately 15 seconds, and is discharged by gravity via a “Y” Funnel into a common Active Storage Bin (AB-44). Keep in mind that the other opening of the “Y” Funnel directs the impregnated tobacco falling from the other stream of Impregnator-Transfer Chute-Declumper and merging the tobacco into the same Active Storage Bin.

Once the tobacco has passed through the Declumper, a platform door in the Transfer Chute (TC-40) opens to allow the operator to clean the bottom lid and seal of the Impregnator before the lid is closed again and the next cycle started.
**Storage and Metering** To ensure that there are no interruptions of tobacco flow to the expansion process, the Active Storage Bin (AB-44) serves as a reservoir for the impregnated tobacco. The Active Storage Bin therefore converts the process from a batch to a continuous process. The Active Storage Bin receives the impregnated tobacco from the Declumper, and has a storage capacity of approximately 4 batches of impregnated tobacco. The Active Storage Bin is a cylindrical bin with a vibrating cone bottom. The bin is double-walled insulated, so it can maintain the product at the correct temperature. The outlet of the cone has a “choke tube” discharge nozzle.

The impregnated tobacco, from the Active Storage Bin, discharges onto Weighing Conveyor (WC-45), which enables precise control of the tobacco, flow to the expansion process. The Weighing Conveyor discharges into the Inlet Rotary Airlock (RV-46) that feeds into the Sublimator (SL-50).

2. **Recovery**

The CO₂ Recovery System operates on a continuous cyclic fashion, which repeats every 7.5 minutes.

CO₂ gas from the Impregnator (V-23) is recovered during de-pressurization to the two recovery tanks; it is then compressed, liquefied and stored in the Process Tank (V-20). The CO₂ gas from the Low Pressure Recovery Tank (T-08) is compressed by the Low Pressure Recovery Compressor (CP-09) and transferred to the High Pressure Recovery Tank (T-10). The CO₂ gas from T-10 is compressed by the High Pressure Recovery Compressor (CP-11) and discharged into the Pressurization Tank (V-19).

When the V-19 tank pressure exceeds the preset operating pressure, an automatic control valve opens and allows the excess pressure to be channeled into the Process Tank V-20. The automatic control valve closes when V-19 pressure drops down to its operating set point.

V-20 operates at a lower pressure than V-19, since CO₂ vapor in V-20 is being chilled and liquefied by the CO₂ Condenser (HE-12), which is connected above the Process Tank (V-20). Liquid CO₂, the condensate, is then being collected in V-20 for reuse.

The Refrigeration System is a closed system using 404A as the coolant. The refrigeration compressor CP-14 compresses the coolant. The hot 404A gas is liquefied in the Refrigerant-Condenser HE-14 by cooling water. A constant level is maintained in the CO₂ Condenser HE-12 by measuring the liquid level in Level Controller LC-1412. The coolant is expanded into the CO₂ Condenser HE-12 and finally returned through the Refrigeration Compressor CP-14.

3. **Liquid CO₂ Storage**

Liquid CO₂ is supplied to the V-20 Process Tank via the CO₂ Supply Pump P-21 from one or two Liquid CO₂ Storage Vessels (V-18).
B. Equipment Description

All high-pressure vessels, valves and piping will be designed and built to local/national codes and regulations using Lloyds or TUV as approval agency.

1. Impregnators V-23A & V-23B (with Swivel Arms)

**Impregnator** The Impregnator is a vertical pressure vessel having quick opening, hinged lids at the top and bottom. The lids utilize a breech lock principle with rotating locking rings, and a pressure relieving safety lock. The Impregnator impregnates cut tobacco with liquid CO₂, processing a batch every 15 minutes.

Upon de-pressurizing the Impregnator to atmospheric pressure the tobacco cells are impregnated with solid CO₂ (dry ice). The impregnated tobacco is discharged from the Impregnator for subsequent processing.

**Swivel Arms** There are four identical Swivel Arms assemblies, two per Impregnator. The main component of each Swivel Arms is the swivel joints. The Swivel Arms are the piping connection between the top and bottom, hinged lids of the Impregnator vessel and the stationary process piping. This enables CO₂ liquid and gas flow to the Impregnator when the lids are closed but also allows the lids to open for tobacco entry and exit.

2. Transfer Chutes TC-40A & TC-40B

Each of the Transfer Chutes receives frozen CO₂ impregnated cut filler tobacco from the Impregnator vessel located directly above. The bottom lid of the Impregnator opens and discharges the mass of frozen tobacco every 15 minutes. The upper portion of the Transfer Chute encloses the bottom lid of the Impregnator and houses the bottom Swivel Arm assembly.

The bottom of the Transfer Chute is attached to the top of a Declumper, DC-41, which loosens the frozen mass of tobacco, and allows it to pass to the Storage Bin via gravity for further processing. The Transfer Chute contains all of the CO₂ vapor generated by the frozen tobacco discharged from the Impregnator.

A ventilation-ducting opening is provided at the chute for exhausting during tobacco dumping. The Transfer Chute has doors that provide access for cleaning and maintenance of both the Impregnator and Declumper.

3. Declumpers DC-41A and DC-41B
Every 15 minutes a mass of frozen tobacco is discharged onto each Declumper from the Impregnator. The Declumper loosens the mass of cut tobacco, which has previously been impregnated with CO₂ liquid and transfers the tobacco by gravity to the Active Storage Bin, AB-44.

4. **Active Storage Bin AB-44 and “Y” Funnel**

The bottom of the two Declumpers are connected to a “Y” Funnel. This allows the frozen tobacco discharged from each Declumper to merge by gravity into one large Active Storage Bin AB-44.

The Active Storage Bin that receives and stores cut, CO₂ impregnated, tobacco from a batch process and subsequently transforms the batch process to a continuous process by discharging the impregnated tobacco at a continuous rate of flow into the Sublimator System in the Hot End.

5. **Weighing Conveyor WC-45**

The Weighing Conveyor receives CO₂ impregnated tobacco (cut filler), which is metered from the Active Storage Bin through a choke tube onto the conveyor. A constant mass flow of tobacco is feed into the Inlet Rotary Valve (RV-46) of the Expansion

6. **Pressurization Tank V-19**

The four main Pressure Vessels are: Pressurization Tank (V-19), Process Tank (V-20), Low Pressure Recovery Tank (T-08), and High Pressure Recovery Tank (T-10).

The Pressurization Tank V-19 is a vertical vessel that is utilized during the Impregnation and Recovery process. In Impregnation, it acts as an intermediate vapor buffer for V-20. In one of the Impregnation sequence, pressure in V-23 is opened to V-19. When V-23 pressure equalizes to V-20, the V-23 / V-19 passage is closed and V-23 / V-20 passage is opened for liquid CO₂ addition.

In Recovery, V-19 accumulates the high-pressure CO₂ gas discharging from the High Pressure Recovery Compressor CP-11. When the tank pressure exceeds the preset operating pressure, an automatic control valve opens and allows the excess pressure to be channeled into the Process Tank V-20. The automatic control valve closes when V-19 pressure drops down to its operating set point.

7. **Process Tank V-20**

The Process Tank V-20 is a horizontal vessel that supplies consumable liquid CO₂ to the Impregnation process. The Process Tank receives vapor CO₂ from V-19. After the vapor is chilled by a refrigeration system, its condensate, liquid CO₂, flows by gravity and accumulates at the bottom of the tank. Also, V-20 holds the replenishments of liquid CO₂ pumped from the Storage Tank V-18.
The Refrigeration System and bayonet type electric heaters help to maintain the pressure / temperature in the Process Tank.

8. **Low Pressure Recovery Tank T-08**

The Low Pressure Recovery Tank receives the second stage of depressurization from the impregnation process, and delivers CO₂ gas to the suction of the Low Pressure Recovery Compressor CP-09.

9. **High Pressure Recovery Tank T-10**

The High Pressure Recovery Tank receives the first stage of depressurization from the impregnation process, and delivers CO₂ gas to the suction of the High Pressure Recovery Compressor CP-11. This tank also provides the purge and first stage of pressurization to the impregnation process.

10. **CO₂ Condenser HE-12**

The CO₂ Condenser (HE-12) is a horizontal shell-and-tube type unit installed in an incline. It condenses CO₂ gas received from the recovery system and returns the CO₂ condensate to the Process Tank. The shell side is single-pass with a transfer medium of Freon 404A and CO₂ is condensed on the tube side.

11. **Low Pressure Recovery Compressor CP-09**

The Low Pressure Recovery Compressor CP-09 compresses CO₂ gas from the Low Pressure Recovery Tank and discharges the CO₂ gas to the High Pressure Recovery Tank. CP-09 is controlled according to pressure in the Low and High Pressure Recovery Tanks.

12. **High Pressure Recovery Compressor CP-11**

The High Pressure Recovery Compressor CP-11 compresses CO₂ gas from the High Pressure Recovery Tank, and discharges the CO₂ gas to the Pressurization Tank V-19.
13. **Refrigeration System CP-14 and HE-14**

This close-loop Refrigeration System provides cooling capacity to the CO₂ Condenser (HE-12) to condense gaseous CO₂ recovered from the impregnation cycle. When refrigeration is required at the CO₂ Condenser, liquid Freon is flashed to a low pressure and temperature. The 404A refrigerant is supplied to the shell side of the CO₂ Condenser, and heat from the warm CO₂ gas in the tubes is transferred to the cool 404A in the shell side, thus vaporizing the A404. The Refrigeration Compressor then compresses this 404A to high pressure and the water-cooled 404A Condenser (HE-14) condenses 404A back to liquid state. A liquid 404A level is maintained in the 404A Receiver (V-14) ensuring ample supply of liquid 404A when required.

The Refrigeration Compressor CP-14 is a multi-capacity type unit. Its variable cooling demand is controlled by the pressure signal from the Process Tank (V-20). As the CO₂ pressure in V-20 gets higher, more cooling capacity will be required, thus, more compression cylinders will be at work.

14. **Process Pump P-22**

The Process Pump is a centrifugal pump that provides a positive force when transfers liquid CO₂ from the Process Tank to the Impregnator to submerge the tobacco in liquid CO₂. Liquid CO₂ is returned to the Process Tank via gravity from the Impregnator after soaking the tobacco.

15. **Silencer S-26**

The stainless steel Silencer reduces the noise generated by the depressurization of a pressure vessel to the atmosphere. It will be mounted outdoors and operates at atmospheric pressure, and is therefore not classified as a pressure vessel.

16. **Connecting Piping & Components**

All Cold End equipment is connected with pressure rated stainless steel pipes. All pre fabricated pressure pipes are X-rayed and pressure tested. All field performed pipe welds are X-rayed and pressure tested according to Airco DIET standard and local code. All components, such as, valves, safety relief valves, pressure gauges, transmitters and etc., in CO₂ service are rated for low temperature.

17. **Liquid CO₂ Storage Vessel V-18 with Refrigeration System**

Liquid CO₂ Storage Vessel V-18 provides the liquid CO₂ for the Process Tank V-20. V-18 is with load-cells as weight indicator. The vessel is vacuum jacketed to reduce heat gain or pressure build-up. An automatic Refrigeration System insures no loss of CO₂ even during long shut-downs.
18. **Liquid CO$_2$ Supply Pump P-21**

The Liquid CO$_2$ Supply pump P-21 transfers the CO$_2$ liquid from the bottom of the Storage Vessel V-18 to the top of Process Tank V-20. The suction pressure is ~18 Bar(g) and discharge is ~29 Bar(g).

**IV. HOT END SYSTEM**

**A. Process Description**

After the cut tobacco is impregnated with CO$_2$ in the Cold End System, it is The Hot End process consists of two phases, (1) Expansion and (2) Reordering. Expansion of the tobacco occurs by rapid heating and resultant drying of tobacco previously treated with carbon dioxide (CO$_2$). Reordering is the restoration of moisture in the previously expanded and dried tobacco, making it acceptable for blending with other tobacco components.

1. **Expansion**

The Hot End process begins at the Rotary Airlock (RV-46). The Rotary Airlock (RV-46) feeds tobacco at a temperature of -78°C continuously from the Active Storage Bin (AB-44) into the Sublimator (SL-50) where it is immediately entrained in the hot gas stream at approximately 250-380°C. Expansion takes place in the Expansion Loop’s Sublimator, which consists of a vertical S-shaped section of round duct. A percentage of the moisture and CO$_2$ entrapped in the tobacco is released into the gas stream. After expansion, the tobacco and process gas mixture enters the Tangential Separator (TS-51) where the expanded tobacco is separated from the gas stream and is continuously discharged from the bottom of TS-51 via the Discharge Rotary Valve (RV-52). The temperature of the discharged expanded tobacco is about 70°-95°C and the moisture content is approximately 1-10%. The process gas exits TS-51 from a side discharge and continues on in the Expansion Loop.

The hot process gas entrained with dust flows to the Cyclone Separator (CS-53) where the fine dust particles are separated and discharged to a bin via the double Rotary Valve (RV-54). Much heat is still contained in the process gas, thus, it is to be recycled. The process gas then passes through the Main Process Gas Fan (PF-55) that provides the motive force for the process gas in the Expansion Loop. Since the process gas is cooled by the dry ice in the tobacco and replenished air introduced into the Loop, much of it must be reheated for it to be useful in the Sublimator. Therefore, from PF-55, the process gas flows to the Process Gas Heater (HE-61). The process gas flows through the tubes of HE-61 and flue gas from the Incinerator (IN-60) flows through the shell side, thus heating the process gas and cooling the flue gas. Process gas exits HE-61 at 600 °C maximum. A variable bypass of the recycled process gas around HE-61 allows the non-reheated recycled process gas to be mixed with the reheated process gas, thus, controls the final
temperature of the process gas. Process gas then flows to the Sublimator (SL-50), completing the Expansion Loop.

Tail gas is removed from the Expansion Loop to suppress dust and volatile organic compounds from accumulating and to balance the pressure in the Sublimator. The Waste Gas Fan (WF-56) draws the tail gas off the recycled process gas stream prior to HE-61. The tail gas and the fume laden air from the Moisture stations is injected into the Incinerator (IN-60) for incineration.

2. **Reordering**

The expanded tobacco discharges from the Tangential Separator via RV-52 onto the Vibrating Conveyor (VC-70). VC-70 is a flow splitting conveyor and discharges an equal flow of expanded tobacco to the Vibrating Conveyors VC-71 A & B. The vibrating motion of these conveyors evenly spreads the tobacco on the conveyor allowing for maximum cooling and release of fumes. Both VC-71 A & B are equipped with a trap door which will remove any burning or smoldering tobacco which may be located in the expanded tobacco. The burning tobacco is detected by a spark detector installed on VC-70. VC-71 A & B then discharges the tobacco onto Band Conveyors BC-72 A & B which both discharge the tobacco onto Band Conveyor BC-73. BC-73 carries the tobacco to the Reordering Cylinder which feeds the Classifying System which removes off spec product such as stem.

Fumes emitted from the hot, dry tobacco while on conveyors VC-70, VC-71 A & B, BC-72 A & B and BC-73 are exhausted through the conveyor fume. The Hood Fan (HF-57) draws the fumes from the hoods and sends it to the incinerator burner, via HE-62. The expanded tobacco, at 1 to 10% moisture, is by BC-73 into the Reordering Cylinder (RC-80). The Reordering Cylinder is a horizontal, rotary cylinder with internal flights which serve to tumble the tobacco as it is conveyed to the discharge of the cylinder. Three zones of air atomizing water spray nozzles are inside the cylinder to apply moisture to the tumbling tobacco. The moisture content of the tobacco is brought back to the level desired for blending. The expanded tobacco exits the Reordering Cylinder at 11 to 12% moisture at a rate of 2280 kg/hr.

A moisture meter is mounted the conveyor unloading the tobacco from the Reordering Cylinder, and senses the moisture of the tobacco exiting the Reordering Cylinder. A PID loop in the meter is used to adjust the amount of water added in the zones of the Reordering Cylinder to maintain correct moisture content.
B. **Equipment Description**


1. **Sublimator SL-50, Expansion Loop and Auxiliary**

The Sublimator expands the impregnated tobacco by contacting it with a high temperature stream for a short period of time. This is accomplished within a high velocity section of ductwork that consists of an Inlet Rotary Airlock RV-46, a vertical run of duct, and ending at the Tangential Separator TS-51. Tobacco is separated from the gas stream in the Tangential Separator and exits through a second rotary valve, RV-52. The Expansion Loop returns the hot gases (after re-heating) back to the beginning of the Sublimator. Auxiliary Ductwork brings moisture and fumes given off by the tobacco after expansion to the Incinerator IN-60 via the Hood Fan HF-57.

2. **Incinerator IN-60 w/ Direct Fired Heat Exchanger HE-61**

The incinerator system consists of one Incinerator, IN-60, and with one Direct Fired Heat Exchanger HE-61. The Incinerator with Heat Exchangers heats or re-heats a process gas stream, heats a waste gas, and incinerates the waste gas stream. The waste gas stream is composed of CO₂, tobacco dust, and volatile organic compounds.

The Incinerator with Heat Exchanger is a complete unit with;

**Fuel Train** The Fuel Train is part of the Incinerator IN-60. It supplies the main fuel for the combustion and controls the temperature inside the Incinerator by modulating the fuel quantity from the fuel supply.

**Burner** The burner will be the Airco DIET standard design. A pilot is initiated by a sparkplug, gaseous fuel and compressed air. After it is confirmed lit, then fuel is added. It is the customer’s choice to select either a fuel oil or gas-burning incinerator.

When town gas or natural gas is selected, the Fuel Train will manifold the gas into a multi-nozzle gas burner. At the same time, waste process and hood air is forced around the nozzles and becomes the combustion air for the gas.

When fuel oil is selected, the fuel oil will be pumped into fuel gun and atomized by compressed instrument air into the oxidizer chamber. Waste process air and hood air is forced into the combustion chamber as the catalyst for combustion.

**Incineration Chamber** The incinerator oxidizes tobacco organics and other hydrocarbons in the waste gas stream. To ensure thermal oxidation of the gas stream,
the residence time of the waste gas can be up to 1 - 2 seconds at a temperature of 4-600 °C. The chamber design ensures well mixing of the gas phase.

**Process Gas Heater HE-61**

HE-61 is a double or single pass shell and tube crossflow heat exchanger. Process gas is heated on the tube side by flue gas from the incinerator on the shell side.

**By-Pass Duct**

A variable by-pass of the process gas around the HE-61 heat exchanger controls the process gas temperature during tobacco expansion. This is achieved by a temperature feedback loop, which controls the opening and closing of a dual-damper motor/actuator unit.

3. **Process Gas Fan PF-55**

The Process Gas Fan PF-55 is a centrifugal type fan. It circulates hot gas through a loop in which tobacco is processed. PF-55 discharges to the Process Gas Heater HE-61 where the gas is heated and then ducted to the point where tobacco enters the loop. The hot gas conveys the tobacco to the Tangential Separator where it is separated from the gas stream and discharged. The gas is first ducted to the Cyclone Separator where fine dust is removed and then to the suction side of the fan completing the loop. Suction dampers having double surface air foil blades are supplied with actuators and adjustable mechanical stops to control the velocity of the gas flow.

4. **Waste Gas Fan WF-56**

The Waste Gas Fan WF-56 is a centrifugal type fan. WF-56 draws a side stream, approximately 5% ~ 20%, from the main process gas stream to maintain a balance of flow in and out of the expansion loop. The waste gas is channeled to the Incinerator combustion chamber for incineration.

6. **Hood Fan HF-57**

The Hood Fan HF-57 is also a centrifugal type fan. HF-57 draws contaminated air and moisture the cooling conveyors. The air is injected into the Incinerator combustion chamber for incineration. Make-up air is added to the suction side of HF-57 as required to provide sufficient air for combustion.

7. **Tangential Separator TS-51**
The Tangential Separator TS-51 extracts tobacco from the process gas/tobacco mixed stream from the Sublimator and discharges the tobacco to atmosphere via a rotary valve, supplied by others, for further processing

8. **Cyclone Separator CS-53**

The Cyclone Separator CS-53 extracts entrained particles from a process gas stream after it is discharge from a Tangential Separator. The particles of dust are discharged via a double rotary air lock to a bin for subsequent disposal.

9. **Inlet Rotary Airlock Valve RV-46**

The Rotary Airlock function is to continuously feeding of tobacco in to the Sublimator. The tobacco at this point is -78°C and the process gas in the Sublimator is at ~250-380°C.

10. **Outlet Rotary Air-Lock Valve RV-52**

Outlet Rotary Valves RV-52 discharges tobacco from the Tangential Separator TS-51. The tobacco at this point is at 75°C when discharged for conveying and further processing.

11. **Dual Cyclone Rotary Air-Lock Valve RV-54**

RV-54 consists of two (2) rotary valves bolted together in series. RV-54 discharges very fine dust from the Cyclone Separator, CS-53. A dual rotary valve insures minimized air leakage into the system.

12. **Vibrating Conveyors VC-70 and 71A/B**

The Vibrating Conveyors VC70 And VC71 Cools the expanded tobacco discharges from RV-52. VC-70 is a flow splitting conveyor and discharges an equal flow of expanded tobacco to the Vibrating Conveyors VC-71 A & B for maximum cooling and release of fumes. Both VC-71 A & B are equipped with spark detector and trap door.

The Conveyors are equipped with hood to capture fumes release from the expanded tobacco.

13. **Band Conveyors BC-72A/B &73**

Band Conveyors BC-72 A & B and 73receives the expanded tobacco from the Vibrating Conveyors and provides the last amount of cooling before the tobacco enters the Reordering Cylinder (RC-80)
14. **Reordering Cylinder RC-80**

The Reordering Cylinder received the expanded tobacco cut filler from the Band Conveyor BC 73. Atomized water is added to achieve a target moisture at the discharge 11 – 12 %. The reordering Cylinder is equipped with Nozzle spray system and controls, internal flights and angle adjustment. The internal nozzle spray system adds moisture to the expanded tobacco as it is tumbled through the cylinder. The nozzles deliver water atomized by compressed air. Spray nozzles are rack-mounted through the interior length of the cylinder.

V. **CONTROLS & INSTRUMENTATION**

A. **Controls**

The Airco DIET Control System always stays at the forefront in the Tobacco Industry. This is achieved by utilizing leading-edge state-of-the-art technology that offers the most reliability, flexibility and the most advanced process control. The System is designed with a high degree of automation to eliminate human errors and thus ensure a high degree of safety.

Programmable Logic Controllers (PLC) is the heart of the Control System. They scan the incoming analog and digital signals from field instruments via an elaborate software program. After this data is manipulated in the software, signals are generated from the PLCs. Data is displayed in legible form on graphic Operator Interface (OI) monitors. Also, commands will be executed from the PLCs to automatically actuate field equipment so that processing conditions of the DIET System are satisfied.

User-friendly Windows based Operator Interface stations are an inseparable part of the DIET System. Besides providing the communication vehicle to execute commands to the PLCs or the field equipment, the OIs also allow operators to diagnose the problems if they arise in the DIET System. When abnormal process conditions or extreme control limits occur, audible alarms will sound. At the same time, the alarm condition will be displayed on the OIs, so that actions will be taken by workers to remedy the alarm condition.

The control software is written, such that, troubleshooting functions are built into the Control System. Soft interlocks are written into the program for maintaining the process integrity and safety. Hardwire interlocks are also implemented to ensure personnel security and safety.

1. **Hardware**

   Electrical hardware, including the PLCs, SMCs, relays, transformers, etc., are housed in lockable electrical panels or Motor Control Centers (MCC). Motor Control Center (MCC)
consists of modular component system that is very easy to apply for controlling and protecting motors. The MCC also offers maximum flexibility for future system expansion, space-saving installation, simple troubleshooting and reliable performance. The MCCs are dust tight IP65 rated and meets IEC and NEC Electrical Codes.

Reliable Programmable Logic Controllers (PLCs), PC-based Operator Interface stations (OI’s) with large size graphic monitors, and touch-screen mini-panels. The OIs and mini-panels are connected to the PLCs via a high-speed communication network.

2. **Software**

Microsoft Windows based software is used. The PLC program is written in ladder logic format. The OIs run WinCC or Wonderware’s Intouch software as a SCADA system to provide real time and historical data throughout the plant floor and for upper management.

For security, four (4) operating security levels are designed into the system. Each higher security level gives added capability to the user so that the Engineer has full capability.

Airco DIET employs the most up-to-date technology in instrumentation to complement the Control System. 25 years of experience in tobacco expansion with ongoing process improvement has ensured our controls/instrumentation selection to guarantee smooth plant operation.

Airco DIET provides advanced and high accuracy instrumentation for the measurement of process data such as Temperature, Pressure, Velocity, Moisture, Level, Weight, Mass Flow and etc.

All inline instruments, which constantly experience pressure, particularly in the CO₂ piping, can be isolated and serviced without depleting the pressure of the line.

**D. CO₂ Safety System**

All precautions are taken for the very unlikely event of a CO₂ leak. CO₂ detectors are strategically placed around the plant to detect the presence of CO₂. The detectors are powered from the factory electric service, but should also be backed up by a factory-provided UPS (Uninterruptible Power Supply) which will keep the alarm system active, even if there is an overall power failure. The monitors warn if a threshold level of CO₂ is detected. The first signal is a yellow alarm light and the common DIET plant alarm; this is a warning of high CO₂ level. It starts the emergency exhaust fans that are rated at 25 room volumes and removes the CO₂ from the building. It also tells the operator to investigate the cause. The second signal is both a red light and a very loud emergency horn indicating a dangerous situation exists and the building must be evacuated.

ADVANTAGES OF DIET OVER WHOLE BLEND EXPANSION
• Vastly Superior Expansion Capability - Depending on the lamina used, the DIET process achieves 80 to 140% expansion compared to less than 20% for most expansion dryers.

• Better preservation of leaf flavor and chemistry – Whole blend expansion exposes all tobaccos to extraordinarily high temperatures which could result in taste and chemistry change and inconsistency. Using a typical Virginia blend with 112% expansion using the DIET process, the same blend filling capacity can be achieved with 18% inclusion of DIET in the final blend as with expansion drying of 100% of the blend at 20% expansion. This allows selection of the most stable tobaccos for the DIET process while preserving the quality of the more volatile tobaccos.

• DIET is less vulnerable to inconsistent infeed – Tobaccos can be highly variable with regard to filling value, particularly across different tobacco types. With whole blend expansion this infeed variability can translate to inconsistent filling capacity of the finished blend which can lead to higher maker weight-related rejects and substandard quality product. The DIET process can be adjusted to maintain a stable and consistent finished filling capacity for a variety of infeed tobaccos.

• Assurance of meeting desired Cigarette Tar is higher with DIET – Cigarette tar is a function of mass, burn rate and construction parameters such as ventilation. Variable blend filling capacity can result in inconsistent weight and burn rate which will impact delivery to the consumer. DIET with its more stable finished filling capacity can minimize rod variability which affects tar. DIET inclusion can be easily adjusted in the blend to help achieve desired targets.

• DIET is truly a product development tool where whole blend expansion is primarily a process enhancement – DIET provides product designers and developers a true tool in which to achieve desired cigarette taste, quality and delivery properties. The primary purpose of a cutfiller dryer is moisture control which is also a critical element of cigarette taste and quality.

• With the challenge to produce superior tasting and performing products in a cost sensitive environment, DIET and whole blend expansion should compliment, not compete with each other. Whole blend expansion can help lower leaf costs but DIET provides greater control over critical finished cigarette parameters and provides taste benefits that cannot be achieved with the use of expanded stems.
DIET Infeed Tobacco

DIET Product
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