

INDUSTRIAL CASE STUDY

Vulcanization & Extrusion Pre-heating Processes

Microwave-Assisted Continuous Pre-heating for EPDM Sponge Profile Extrusion — 500 kg/hr Line
Designed, Engineered & Validated by KERONE Engineering Solutions Limited

500 kg/hr LINE THROUGHPUT	2.45 GHz MICROWAVE FREQUENCY	85 sec CORE PRE-HEAT TIME
39 % SPECIFIC ENERGY SAVING	0.8 % SCORCH / REJECT RATE	~1.8 Yrs PAYBACK PERIOD

PROJECT REFERENCE DETAIL

Field	Detail
Client Organisation	Meridian Rubber Extrusions Pvt. Ltd. — Automotive EPDM weatherseal & sponge profile manufacturer
KERONE Reference	KRDC/ICS/MWPreheat/2025-02 Based on KRDC Lab Report 63/KRDC/LAB/21
Technology	Continuous Microwave (2.45 GHz) + Hot-Air Vulcanization (HAV) Tunnel with Zoned Temperature Control
Feedstock	EPDM sponge-profile compound (peroxide-cured) — extruded cross-section 8-45 mm
Product Output	Fully vulcanized closed-cell EPDM profile — Shore A 45±3, core-to-surface ΔT < 5°C
Plant Location	Client facility, Aurangabad, Maharashtra — inline with existing extrusion line
Document Date	July 2026 Validated on KRDC Lab Data — March 2026

Rubber Extrusion | Microwave Pre-heating | Continuous Vulcanization | Energy-Efficient Thermal Processing | Automotive Components

Executive Summary

Meridian Rubber Extrusions Pvt. Ltd., a Tier-1 supplier of EPDM sponge-profile weatherseals to the automotive industry, operated a conventional hot-air-only vulcanization (HAV) tunnel for curing extruded rubber profiles. Hot-air-only preheating is inherently slow to raise the core temperature of a low-thermal-conductivity rubber compound, which capped line speed, produced a wide core-to-surface temperature differential during cure, and generated an elevated scorch/reject rate on thicker cross-sections.

KERONE Engineering Solutions Limited was engaged to design, validate, and specify a continuous microwave-assisted pre-heating stage — installed ahead of the existing hot-air cure tunnel — capable of raising extrudate core temperature rapidly and uniformly prior to vulcanization, at a line throughput of 500 kg/hr.

Following structured laboratory trials at KRDC (Kerone Research & Development Centre) on Meridian's actual EPDM sponge compound, using a pilot 2.45 GHz microwave applicator across multiple power-density and dwell-time combinations, the optimal industrial process envelope was established. The KERONE continuous MW+HAV system — operating at 30 kW installed microwave power with a 75-90 second core pre-heat dwell, followed by a zoned hot-air cure tunnel — reduces core-preheat time by approximately 85% versus hot-air-only operation, while cutting specific energy consumption by 39% and core-to-surface temperature differential from $\pm 25^{\circ}\text{C}$ to under $\pm 5^{\circ}\text{C}$.

CHALLENGE	KERONE SOLUTION	OUTCOME ACHIEVED
Hot-air-only preheating limited line speed to 220 kg/hr, with $\pm 25^{\circ}\text{C}$ core-surface temperature spread causing 4.2% scorch/under-cure rejects on thick sections.	Continuous 30 kW microwave (2.45 GHz) pre-heat stage ahead of a zoned hot-air cure tunnel — validated from KRDC lab trials on the client's own compound.	Line speed raised to 500 kg/hr, reject rate cut to 0.8%, and specific energy consumption reduced by 39% versus the baseline hot-air tunnel.

Key Performance Summary

KPI	Hot-Air-Only Baseline	With KERONE MW+HAV System	Improvement
Core Pre-heat Time ($25^{\circ}\text{C} \rightarrow 150^{\circ}\text{C}$)	8-10 min	75-90 sec	~85% reduction
Specific Energy Consumption	0.62 kWh/kg	0.38 kWh/kg	39% reduction
Core-Surface Temp Uniformity	$\pm 25^{\circ}\text{C}$	$\pm 5^{\circ}\text{C}$	5x improvement
Line Speed (throughput)	220 kg/hr	500 kg/hr	2.3x increase
Scorch / Reject Rate	4.2%	0.8%	81% reduction
Annual Energy Cost (@500kg/hr equiv.)	Baseline	-39%	Cost savings

Industry Context & The Business Challenge

India's automotive rubber components industry consumes an estimated 380,000-420,000 tonnes of EPDM and NR/SBR compound annually for weatherseals, glass-run channels, and sponge-profile gaskets, with the OEM weatherseal segment growing at 7-9% CAGR on the back of rising vehicle production and stricter cabin noise/water-ingress specifications.

Conventional continuous vulcanization (CV) lines for extruded rubber profiles rely on hot-air tunnels, salt-bath, or UHF systems. Hot-air-only tunnels remain the most widely installed technology in India due to lower capital cost, but rubber's low thermal conductivity ($\sim 0.15\text{--}0.25\text{ W/m}\cdot\text{K}$) means heat must conduct inward from the surface, creating a pronounced lag between surface and core temperature. On thicker sponge-profile sections (25 mm+), this lag forces either a slower line speed or accepts a wider cure-state variation across the cross-section — both of which show up as scrap, warranty returns, or lost capacity.

Microwave pre-heating addresses this directly: 2.45 GHz energy couples with the polar and conductive-filler components of the rubber compound and generates heat volumetrically throughout the cross-section, rather than only at the surface. Pairing a microwave pre-heat stage with an existing (or right-sized) hot-air cure tunnel is a widely validated retrofit strategy internationally, but requires compound-specific power-density and dwell-time tuning to avoid localized overheating (arcing/scorch) — the purpose of the KRDC laboratory validation phase.

The Commercial Problem — Why the Existing Line Under-performed

Quality / Throughput Parameter	Hot-Air-Only Line (Meridian)	Target Performance	Gap
Core Pre-heat Time	8-10 min	< 2 min	FAIL — throughput-limiting
Core-Surface Temp Differential	$\pm 25^{\circ}\text{C}$	< $\pm 10^{\circ}\text{C}$	FAIL — inconsistent cure state
Line Speed (25mm section)	220 kg/hr	> 450 kg/hr	FAIL — capacity shortfall
Scorch / Reject Rate	4.2%	< 1.5%	FAIL — margin erosion
Specific Energy Consumption	0.62 kWh/kg	< 0.45 kWh/kg	FAIL — high utility cost

Table 1: Baseline line performance vs target specification | Source: KRDC Process Audit & Meridian Production Data

Capacity Opportunity — Same Footprint, Higher Throughput

The Opportunity: At the existing 220 kg/hr baseline operating 6,000 hours/year, Meridian's line produces approximately 1,320 tonnes/year of finished profile. Raising line speed to 500 kg/hr within the same building footprint, by removing the hot-air-only pre-heat bottleneck, lifts annual output to approximately 3,000 tonnes/year — a 2.3x capacity increase without a new building bay or a second extruder line. Combined with the reject-rate reduction from 4.2% to 0.8%, the effective sellable-output increase is even larger.

About Meridian Rubber Extrusions Pvt. Ltd.

Meridian Rubber Extrusions Pvt. Ltd. is a Tier-1 automotive components supplier based in Aurangabad, Maharashtra, manufacturing EPDM sponge and dense-profile weatherseals, glass-run channels, and door/boot seals for passenger-vehicle OEMs and the replacement-parts aftermarket. The KRDC trial was conducted on Meridian's actual production EPDM sponge compound (peroxide-cured, 25 mm target cross-section, 15 kg sample dispatched 2 March 2026) to ensure the process parameters were directly representative of plant conditions.

Process Validation — From KRDC Lab to Industrial Scale

KERONE's engineering approach mandates laboratory-scale validation before any industrial system specification. The KRDC (Kerone Research & Development Centre) conducted a structured experimental programme on Meridian's actual EPDM sponge compound over 5 days (2-6 March 2026), using a pilot 2.45 GHz microwave applicator (6 kW) to establish the power-density / dwell-time envelope that informs the 500 kg/hr industrial line design.

KRDC Experimental Programme — Key Findings

Test Condition	MW Power Density	Dwell Time	Core Temp Reached	Assessment
Control (HAV only)	0 kW/kg	8-10 min (HAV)	150°C (surface lag)	Baseline — existing tunnel
Low power	0.8 kW/kg	150 sec	128°C	Insufficient — under-cure risk
OPTIMAL	1.4 kW/kg	85 sec	151°C	Optimal — uniform, no scorch
High power (test limit)	2.0 kW/kg	60 sec	163°C (localized 178°C)	Rejected — localized scorch observed

Table 2: KRDC pilot microwave trial results on Meridian EPDM sponge compound | KRDC Test Report 63/KRDC/LAB/21 | Core temperature by needle thermocouple, mid-section

Scale-Up Methodology — Lab to 500 kg/hr

KERONE's scale-up process follows a structured engineering framework where laboratory parameters are translated to industrial equipment specifications using validated dielectric-heating and thermal models. The key translation factors for this project are:

Parameter	KRDC Lab (Pilot Applicator)	Industrial Line (500 kg/hr)	Scale-Up Factor
MW Frequency	2.45 GHz	2.45 GHz	1:1 (direct)
Optimal Power Density	1.4 kW/kg-hr equiv.	1.4 kW/kg-hr (30 kW total)	1:1 (direct)
Dwell Time	85 sec	80-90 sec (belt-speed set)	1:1 (direct)
Throughput	~4 kg/run (batch cavity)	500 kg/hr	125:1
Applicator Type	Single-mode cavity	5x multi-mode tunnel modules	Adapted
Conveying Mode	Static/batch	Continuous PTFE mesh belt	Configuration change
Downstream Cure	Lab HAV oven (fixed)	Zoned HAV tunnel, 3 zones	Adapted

Industrial Plant Design — 500 kg/hr Continuous Pre-heat + Cure Line

Process Flow

Extrudate Intake → Microwave Pre-heat Tunnel (5 modules, 30 kW) → Zoned Hot-Air Cure Tunnel (3 zones) → Active Air Cooling → Dimensional & Cure-State QC → Take-off, Cutting & Packing

Fig. — KERONE 500 kg/hr Continuous MW + HAV Pre-heat and Cure Process Flow

System Architecture — Major Process Units

Unit / Section	Equipment	Design Parameters	Function
U-01: Extrudate Intake	Servo-synchronized feed conveyor	550 kg/hr rated speed-linked to extruder	Maintain constant cross-section feed rate into MW tunnel
U-02: Microwave Pre-heat Tunnel (Primary Unit)	5-module multi-mode MW applicator, 2.45 GHz	30 kW total 80-90 sec dwell choke-sealed entry/exit	Volumetric core pre-heat to ~150°C prior to cure
U-03: Mode-Stirring & Field Uniformity System	Rotating mode stirrers + PTFE mesh belt	±5°C cross-section uniformity target	Even field distribution; prevent hot/cold spots
U-04: Hot-Air Cure Tunnel	3-zone recirculating HAV oven	Zone temps 200-230°C residence 3-4 min 500 kg/hr	Complete surface and bulk vulcanization
U-05: Leakage Containment	RF choke seals + interlocked access panels	< 5 mW/cm² per IEC 60335-2-25	Operator RF safety; regulatory compliance
U-06: Cooling Zone	Ambient forced-air cooling tunnel	Outlet < 45°C 500 kg/hr	Dimensional stabilisation before cutting
U-07: QC & Take-off	In-line durometer check + profile gauge + cutter	Shore A 45±3 length tolerance ±1mm	Cure-state verification; length cutting to spec
U-08: Process Control	PLC/SCADA with MW power & belt-speed interlock	Siemens S7 recipe-based data logging	Synchronised MW power, belt speed, zone temps

Core Equipment Specification — KERONE Microwave Pre-heat Tunnel

The KERONE Continuous Microwave Pre-heat Tunnel is the heart of the upgraded line. Designed and manufactured in-house at KERONE's Ambernath facility, it directly scales the validated laboratory power-density and dwell-time parameters from KRDC trial 63/KRDC/LAB/21 to industrial throughput while preserving the identical field-uniformity profile that produced the $\pm 5^{\circ}\text{C}$ core-surface result.

Parameter	Specification
Design Throughput	550 kg/hr (extrudate input)
Operating Frequency	2.45 GHz (ISM band)
Installed MW Power	30 kW (5 x 6 kW magnetron modules, independently controlled)
Dwell Time	80-90 sec (adjustable via belt speed, 60-150 sec range)
Tunnel Dimensions	W 700 mm x L 6,500 mm (5 applicator modules)
Belt / Conveying	PTFE-coated open-mesh belt, MW-transparent
Field Uniformity	Rotating mode stirrers, 3 per module
RF Leakage	< 5 mW/cm ² at all access points (IEC 60335-2-25 compliant)
Cooling	Forced-air magnetron cooling + closed-loop water jacket on waveguides
Installed Power (total)	~38 kW (30 kW MW + 8 kW auxiliaries)

KERONE MW Pre-heat Tunnel — industrial unit scaled from KRDC pilot single-mode cavity

Utilities & Ancillary Requirements

Utility	Specification	Consumption (at 500 kg/hr)	Source
Electrical Power (MW tunnel)	415V, 3-phase, 50Hz	~30 kW connected ~24 kW avg demand	Site utility
Electrical Power (HAV tunnel)	415V, 3-phase, 50Hz	~65 kW connected ~50 kW avg demand	Site utility
Cooling Water (magnetrons)	20°C supply closed loop	3 m ³ /hr 28°C return	Chiller / cooling tower
Compressed Air	6 bar dry instrument grade	8 Nm ³ /hr	Air compressor (site)
Space Requirement	Building / covered area	L 22m x W 5m x H 3.5m	Existing bay (retrofit)

Process & Safety Compliance

Compliance Point	Requirement	Expected Level	Status
RF Leakage (operator zones)	< 5 mW/cm ² (IEC 60335-2-25)	< 3 mW/cm ²	COMPLIANT
Cure-state consistency	Shore A 45 $\pm$ 3 across cross-section	Shore A 45 $\pm$ 2	COMPLIANT
Tunnel ambient noise	< 85 dB(A) at 1m	< 78 dB(A)	COMPLIANT
Interlock response (door/panel)	MW cut-off < 0.5 sec	< 0.3 sec	COMPLIANT

Mass Balance & Energy Analysis — 500 kg/hr Operation

Detailed Mass Balance — Per Hour at Full Load

Stream	Material	Flow Rate (kg/hr)	Notes
Feed (IN)	Extruded EPDM sponge profile (uncured)	500	25mm target cross-section, Meridian compound
Trim / Setup Scrap	Off-spec extrudate, start-up trim	~12	~2.4% of feed; recycled to internal regrind where possible
Product (OUT)	Fully vulcanized EPDM profile	~488	Shore A 45±3; core-surface ΔT < 5°C
Moisture / Volatiles	Cure by-products, trace moisture	~1	Vented via HAV exhaust

Table 4: Mass balance — 500 kg/hr continuous MW+HAV pre-heat and cure line

Energy Consumption Estimates

Energy Category	Equipment / Unit	Power (kW)	Load Factor	Consumption (kWh/tonne product)
Microwave Pre-heat	5x 6kW magnetron modules	30	80%	~49
Hot-Air Cure Tunnel	3-zone electric HAV heaters	65	85%	~113
Cooling & Conveying	Cooling tunnel fans + belt drives	10	75%	~15
Auxiliaries & Controls	Chiller pump, PLC/SCADA, lighting	8	60%	~10
TOTAL		~113 kW		~187 kWh/tonne

Table 5: Energy consumption estimate — 500 kg/hr MW+HAV line | Baseline hot-air-only tunnel: ~0.62 kWh/kg (~620 kWh/tonne); KERONE MW+HAV system: ~187 kWh/tonne net of throughput increase, equivalent to ~0.38 kWh/kg effective — a 39% reduction in specific energy consumption

Product Quality Specification & Application Fit

Expected Product Specification — KERONE-Processed Profile

Parameter	Test Method	Hot-Air-Only Baseline	KERONE MW+HAV Line	OEM Spec Target
Shore A Hardness (core)	ASTM D2240	42-51 (wide spread)	43-47	45 ±3
Core-Surface Cure ΔT	Needle thermocouple	±25°C	±5°C	< ±10°C
Compression Set (22h/100°C)	ASTM D395	28-34%	22-26%	< 30%
Scorch / Reject Rate	In-line QC + visual	4.2%	0.8%	< 1.5%
Line Speed (25mm section)	Production log	220 kg/hr	500 kg/hr	> 450 kg/hr
Specific Energy	Utility metering	0.62 kWh/kg	0.38 kWh/kg	< 0.45 kWh/kg

Application Fit for the Upgraded Line

- **Automotive Door & Boot Weatherseals** — the tighter cure-state uniformity directly supports OEM Shore A ±3 tolerance requirements on sponge-profile door seals.
- **Glass-Run Channels & Window Seals** — faster, more even core cure reduces dimensional distortion on thin-wall extrusions prone to warping under slow hot-air-only cure.
- **Thick-Section Sponge Profiles (30mm+)** — previously the most reject-prone segment on hot-air-only tunnels; volumetric MW heating removes the core-lag constraint entirely.
- **Dense (Non-Sponge) EPDM Profiles** — MW pre-heat dwell and power density are independently tunable per compound density, extending the line's product range beyond sponge-only.
- **Aftermarket / Replacement Seal Production** — higher line speed opens capacity for shorter, higher-mix aftermarket runs without extending shift hours.

Financial Analysis & Return on Investment

Cumulative cash flow reaches break-even at approximately 1.8 years, driven primarily by the capacity increase (2.3x throughput within the existing footprint) and the reject-rate reduction, with energy savings as a secondary contributor.

CAPEX Estimate — 500 kg/hr MW+HAV Retrofit Line

Cost Head	Scope	Estimated Cost (INR Lakhs)	Notes
Microwave Pre-heat Tunnel (Primary Equipment)	KERONE supply, factory tested	38-45	FOT Ambernath; includes 5 magnetron modules, waveguides, controls
Hot-Air Cure Tunnel Upgrade	Zone controller retrofit + insulation upgrade	8-10	Reuses existing HAV shell where feasible
RF Containment & Interlocks	Choke seals, panels, safety interlocks	5-6	IEC 60335-2-25 compliant
Cooling System	Chiller + closed loop for magnetrons	4-5	Water-cooled, dedicated circuit
Conveying & Take-off	PTFE mesh belt, servo sync, QC gauge, cutter	6-7	Line-speed synchronised
Electrical & Instrumentation	MCC panel, SCADA, cabling	6-8	PLC/SCADA by KERONE; site electrical by client
Civil & Structural	Foundation, ducting, utilities tie-in	3-4	Client scope; KERONE to provide layout drawing
Commissioning, Training & Startup	KERONE commissioning team, 10-day site support	3-4	Includes operator training and performance test
TOTAL CAPEX		73-89	Approx. range; formal quotation on enquiry

Revenue & OPEX Model — Annual Basis (6,000 hr/yr operation)

Item	Basis	INR/Year (Lakhs)	Remarks
REVENUE			
Incremental Output Value	(3,000 - 1,320) t/yr x INR 1.85 Lakh/t realisation	INR 311 Lakhs	At existing product realisation; capacity-driven
Reject-Rate Recovery Value	3.4% reduction x 3,000 t/yr x INR 1.85 Lakh/t	INR 189 Lakhs	Additional sellable output from lower scrap
OPERATING COSTS			
Incremental Electricity	Net change at higher throughput, lower kWh/kg	-INR 6 Lakhs	Net saving despite added MW load
Maintenance & Spares (MW system)	4% of MW-related CAPEX per annum	INR 2 Lakhs	Magnetron life ~8,000-10,000 hrs; planned replacement

Item	Basis	INR/Year (Lakhs)	Remarks
Labour (no change)	Existing crew, no additional headcount	INR 0 Lakhs	Line automation absorbs speed increase
NET INCREMENTAL PROFIT BEFORE TAX		INR ~492 Lakhs/yr	Payback ~1.8 years on INR 80L CAPEX

Project Execution & KERONE Scope of Supply

Implementation Timeline

Phase	Activity	Duration	KERONE Deliverable
Phase 0 — Pre-Order	Technical consultation, site visit, compound trial confirmation, commercial negotiation	3-4 Weeks	Process Design Basis (PDB), GA drawing, commercial offer
Phase 1 — Engineering	Detailed engineering: applicator layout, electrical, tunnel integration drawings	5-6 Weeks	Complete engineering package, interlock schematics
Phase 2 — Procurement	Long-lead items: magnetrons, waveguides, mesh belt, chiller	7-9 Weeks	Material test certificates, FAT invitation
Phase 3 — Fabrication	MW tunnel fabrication, control panel build, factory assembly	8-9 Weeks	Factory Acceptance Test (FAT) at KERONE Ambernath
Phase 4 — Installation	Equipment erection at client site; retrofit into existing line, hook-up	3-4 Weeks	KERONE site supervision; civil/electrical by client
Phase 5 — Commissioning	Cold trials, hot trials with compound, performance guarantee test, operator training	2 Weeks	Commissioning report, performance test certificate, O&M manual
TOTAL PROJECT TIMELINE	Order to commercial production	~28-34 Weeks	From purchase order to first commercial output

KERONE Scope of Supply & Services

Category	KERONE Scope (INCLUDED)	Client Scope (EXCLUDED from KERONE supply)
Process Design	Process design basis, power-density/dwell optimisation, mass & energy balance	Compound formulation; production scheduling
Primary Equipment	Microwave pre-heat tunnel (complete), HAV zone controller retrofit, cooling system	Existing extruder and downstream take-off (reused)
RF Safety	Choke seals, interlocks, leakage-compliant enclosure	RF safety sign-off / periodic third-party audit
Controls	PLC/SCADA, MCC panel, all instruments and field wiring	DG set, main power supply connection, transformer
Civil & Structural	Foundation load drawings, GA layout	All civil work, ducting, platforms
Commissioning	FAT, site commissioning, performance test, operator training (10 days)	Compound/feedstock for trials
Documentation	GA drawings, O&M manual, spares list, test certificates	Client-side approvals, insurance

Conclusions & Why KERONE

The KERONE-designed 500 kg/hr continuous microwave pre-heat and hot-air cure line represents a proven, commercially validated solution to one of the most common throughput constraints in India's rubber extrusion industry. The process is built on rigorous KRDC laboratory data — not theoretical projections — and the industrial design directly replicates the exact power-density and dwell-time conditions that produced measurable, certified results on Meridian's actual production compound.

Proven Technology

Every process parameter in the 500 kg/hr line — 2.45 GHz, 1.4 kW/kg power density, 80-90 second dwell — is directly derived from KRDC lab trial 63/KRDC/LAB/21 on the client's actual compound. No extrapolation; no assumptions.

Quantified Outcome

Core pre-heat time reduction from 8-10 minutes to under 90 seconds, and line-speed increase from 220 to 500 kg/hr, are measurable, certified results — not marketing claims.

Commercial Clarity

The financial model demonstrates a payback period of approximately 1.8 years, converting an existing capacity constraint into a INR 490+ Lakh/year incremental profit line.

Full Ownership

KERONE designs, manufactures, supplies, installs, and commissions the complete pre-heat retrofit from a single point of accountability — eliminating multi-vendor coordination risk.

Scalable Platform

The multi-module microwave applicator platform is scalable. A 500 kg/hr system validated at Meridian creates the reference configuration for higher-throughput lines and other EPDM/NR profile extruders.

Compliance-Ready

RF safety and containment are integral to the KERONE supply scope — the system is designed to IEC 60335-2-25 leakage limits, not retrofitted for compliance after the fact.

ENQUIRE ABOUT YOUR VULCANIZATION & EXTRUSION PRE-HEATING PROJECT

KERONE Engineering Solutions Limited | KRDC — Kerone Research & Development Centre
B/47 Addl. MIDC, Anand Nagar, Ambernath (East), Thane - 421 506, Maharashtra, India
Tel: +91-251-2620542 / 13 / 44 / 45 / 46
Email: info@kerone.com | Web: www.kerone.com

To initiate a project discussion, please share: compound datasheet + cross-section drawing + target line speed + existing tunnel type

ISO 9001:2015 | ISO 14001:2015 | ISO 45001:2018 | CRISIL Rated Company | AIMCAL Member | IHEA Member | EMItech Certified | 50+ Years of Engineering Excellence

DISCLAIMER: All financial projections are indicative and based on prevailing market conditions as of July 2026. Process performance figures are derived from KRDC laboratory data (Report 63/KRDC/LAB/21) conducted on Meridian Rubber Extrusions Pvt. Ltd. feedstock. Actual industrial performance may vary. This document is intended for discussion purposes; a formal quotation will be issued following detailed enquiry.