Utilizing Advancements in Simulation to Improve Occupational Health and Safety

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REV 3

Key Objectives

KEY OBJECTIVES

IDENTIFY ENVIRONMENTAL HAZARDS

PREDICTING ENVIRONMENTAL HAZARDS

COMPARE SOLUTIONS AND MITIGATE ENVIRONMENTAL HAZARDS

Early Work in Industrial Hygiene

EARLY WORK IN INDUSTRIAL HYGIENE

- **HEAVY INDUSTRY = POOR REPUTATION REGARDING HEALTH AND SAFETY**
- **OVER 500 DEATHS IN ONE CALENDAR YEAR IN THE PITTSBURGH AREA**
- **EMPLOYERS SUGGEST 95% OF ACCIDENTS ARE THE FAULT OF EMPLOYEES**
- **RESEARCH BEGINS TO SHOW OTHERWISE**
  - **CRYSTAL EASTMAN PUBLISHED *WORK ACCIDENTS AND THE LAW***

EARLY WORK IN INDUSTRIAL HYGIENE

- **DATA WAS COLLECTED OVER A ONE YEAR PERIOD IN PITTSBURGH**

- **THREE ASPECTS OF THE ACCIDENT WERE INVESTIGATED**
  - **THE NATURE OF THE ACCIDENT**
  - **WHO WAS AT FAULT**
  - **ECONOMIC IMPACT ON FAMILIES**

- **THREE INDUSTRIAL SECTORS WERE INVESTIGATED**
  - **RAILROADS**
  - **MINES**
  - **STEEL MILLS**

EARLY WORK IN INDUSTRIAL HYGIENE

- **CRYSTAL EASTMAN’S RESEARCH DETERMINED THE FOLLOWING:**
  - **30% OF THE ACCIDENTS WERE THE FAULT OF THE EMPLOYER**
  - **44% OF THE ACCIDENTS COULD BE BLAMED ON THE EMPLOYEES**

- **DATA COLLECTED POINTED TO CERTAIN PRE-CONDITIONS**
  - **LONG WORK HOURS**
  - **TEMPERATURE EXTREMES / ENVIRONMENT**
  - **NOISE**
  - **HIGH SPEED MACHINERY**

EARLY WORK IN INDUSTRIAL HYGIENE

- **ADDITIONAL RESEARCH**
  - **DOCUMENTED CASES DATING BACK TO 1556**
  - **DR. ALICE HAMILTON**
    - **PIONEER IN INDUSTRIAL TOXICOLOGY**
    - **CONSIDERED FOUNDER OF MODERN INDUSTRIAL HYGIENE**
  - **MR. BENJAMIN McCREADY**
    - **PUBLISHED *ON THE INFLUENCE OF TRADES, PROFESSIONS AND OCCUPATIONS IN THE UNITED STATES* IN 1837**
    - **CONSIDERED FIRST WORK ON OCCUPATIONAL MEDICINE PUBLISHED IN THE UNITED STATES**

EARLY WORK IN INDUSTRIAL HYGIENE

- **RESEARCH LED TO:**
  - **CREATION OF US DEPARTMENT OF LABOR**
  - **OSHA**

- **USING ADVANCED SIMULATION, WE CAN ADVANCE THE WORK OF THESE EARLY PIONEERS**

How Can CFD Modeling be Applied to Protect Employees?

COMPUTATIONAL FLUID DYNAMIC MODELING

- **COMPUTATIONAL FLUID DYNAMIC (CFD) MODELING IS THE SCIENCE OF:**
  - **PREDICTING FLUID FLOW**
  - **HEAT AND MASS TRANSFER**

- **AUTODESK CFD SOFTWARE IS USED**

- **HOW CAN CFD BE APPLIED TO INDUSTRIAL HYGIENE?**

COMPUTATIONAL FLUID DYNAMIC MODELING

- **CFD CAN BE APPLIED TO PREDICT:**
  - **THE EFFICIENCY OF EMISSION CAPTURE HOODS**
  - **THERMAL STRESS**
  - **HOW GAS MOVES THROUGH A BUILDING**

COMPUTATIONAL FLUID DYNAMIC MODELING

- **WHY CFD OVER OTHER METHODS?:**
  - **ACCOUNTS FOR ALL INTERNAL AND EXTERNAL INFLUENCES**
    - **CROSS WINDS**
    - **HIGH TEMPERATURE PROCESSES**
  - **LESS EXPENSIVE THAN TRADITIONAL PHYSICAL WATER MODELS**
  - **OUTPUT QUANTIFIES RESULTS**
    - **PROVIDES A CAPTURE EFFICIENCY**
    - **PROVIDES A INLET OR OUTLET PRESSURE**
    - **SHOWS GRADIENTS**

Identifying Environmental Hazards

PARTICULATE

- **THREE CLASSES**
  - **PM / TSP**
    - **BROAD TERM TO INCLUDE ALL PARTICULATE MATTER**
  - **PM_{10}**
    - **PARTICULATE MATTER LESS THAN 10 MICRONS**
  - **$PM_{2.5}$**
    - **PARTICULATE MATTER LESS THAN 2.5 MICRONS**

PARTICULATE

- **FORMED AS FOLLOWS:**
  - **MECHANICAL PROCESS**
    - **MINING**
    - **TRANSFER POINTS**
    - **MECHANICAL FABRICATION**
    - **ROADS AND VEHICLES**
    - **WELDING**
  - **CHEMICAL REACTIONS**
    - **KISH**

PARTICULATE

- **WHY SHOULD WE BE CONCERNED?**
  - **VERY SMALL PARTICLES CANNOT BE SEEN BY THE HUMAN EYE**
    - **HUMAN HAIR DIAMETER 40-80 MICRONS**
    - **TYPICAL RED BLOOD CELL IS 5 MICRONS**
  - **VERY SMALL PARTICLES CAN BE INHALED**
  - **CAUSES RESPIRATORY ISSUES WHEN INHALED**

PARTICULATE

- **EXPOSURE LIMITS FOR SELECT MATERIALS**

Contaminant	Exposure Limit
Iron Oxides (fume)	10 mg/m^3
Lead	50 $\mu g/m^3$
Manganese Fume	15 mg/m^3
Kish	5 mg/m^3
Chromium IV Compounds	5 $\mu g/m^3$

THERMAL STRESS

- **A HUMAN'S MEANS OF CONTROLLING INTERNAL TEMPERATURE BEGINS TO FAIL**

- **THREE FACTORS INFLUENCE THERMAL STRESS**
  - **ENVIRONMENT**
  - **CLOTHES**
  - **ACTIVITY**

THERMAL STRESS

- **TYPICAL METABOLIC RATES**

Activity	Metabolic Rate (W/m^2)
Standing	70
Walking slowly	115
Walking moderately	150
Walking briskly	220
Lifting/packing	120
Pick and shovel work	235-280
Light machine work	115-140
Heavy machine work	235

THERMAL STRESS

- **TYPICAL CLOTHING FACTORS**

Clothing	I_{cl} (clo)
Trousers w/short sleeve shirt	0.57
Trousers w/long sleeve shirt	0.61
Overalls, long pants, flannel shirt	1.37

CARBON MONOXIDE

- **INCOMPLETE COMBUSTION OF CARBON CONTAINING FUELS**
  - **ODORLESS**
  - **COLORLESS**
  - **SENSES CANNOT DETECT CARBON MONOXIDE**

- **HEMOGLOBIN TRANSPORTS OXYGEN IN BLOOD**
  - **PREFERS CO TO OXYGEN**
  - **CO WILL DISPLACE OXYGEN**

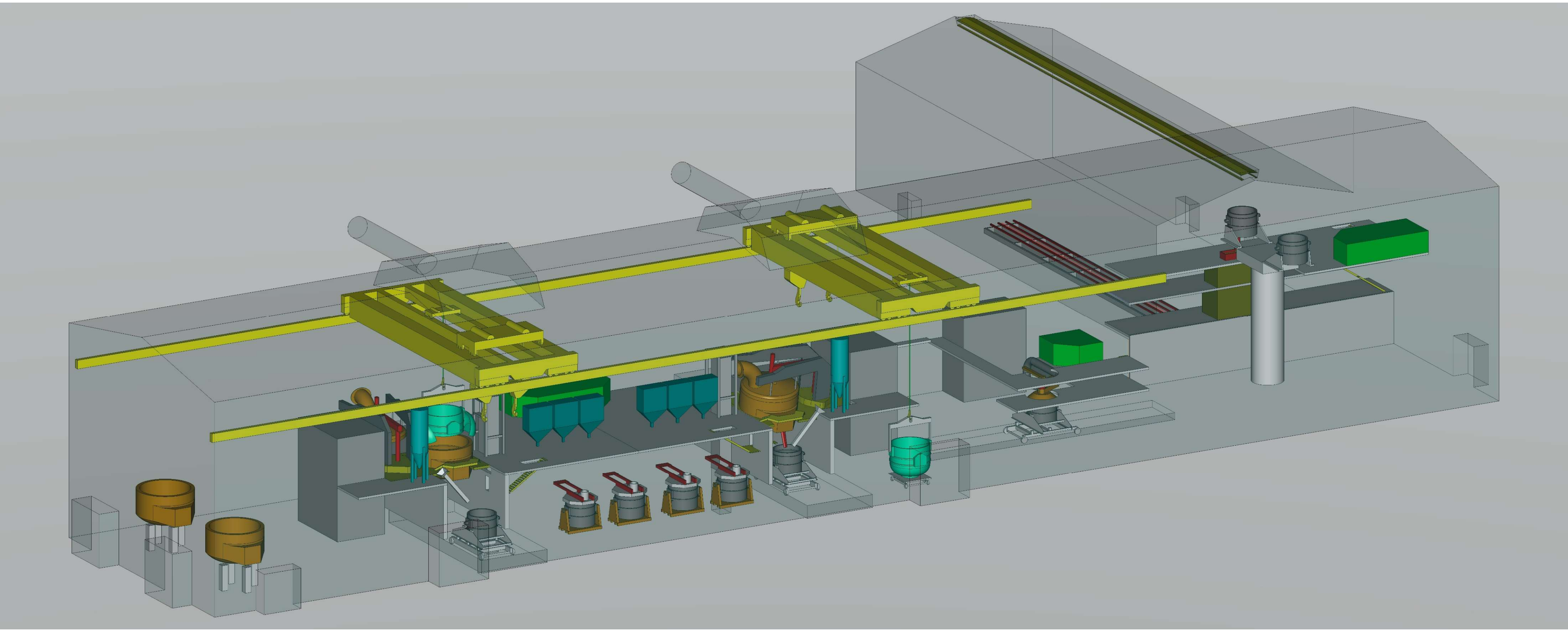
CARBON MONOXIDE

- **SYMPTOMS OF CARBON MONOXIDE EXPOSURE**

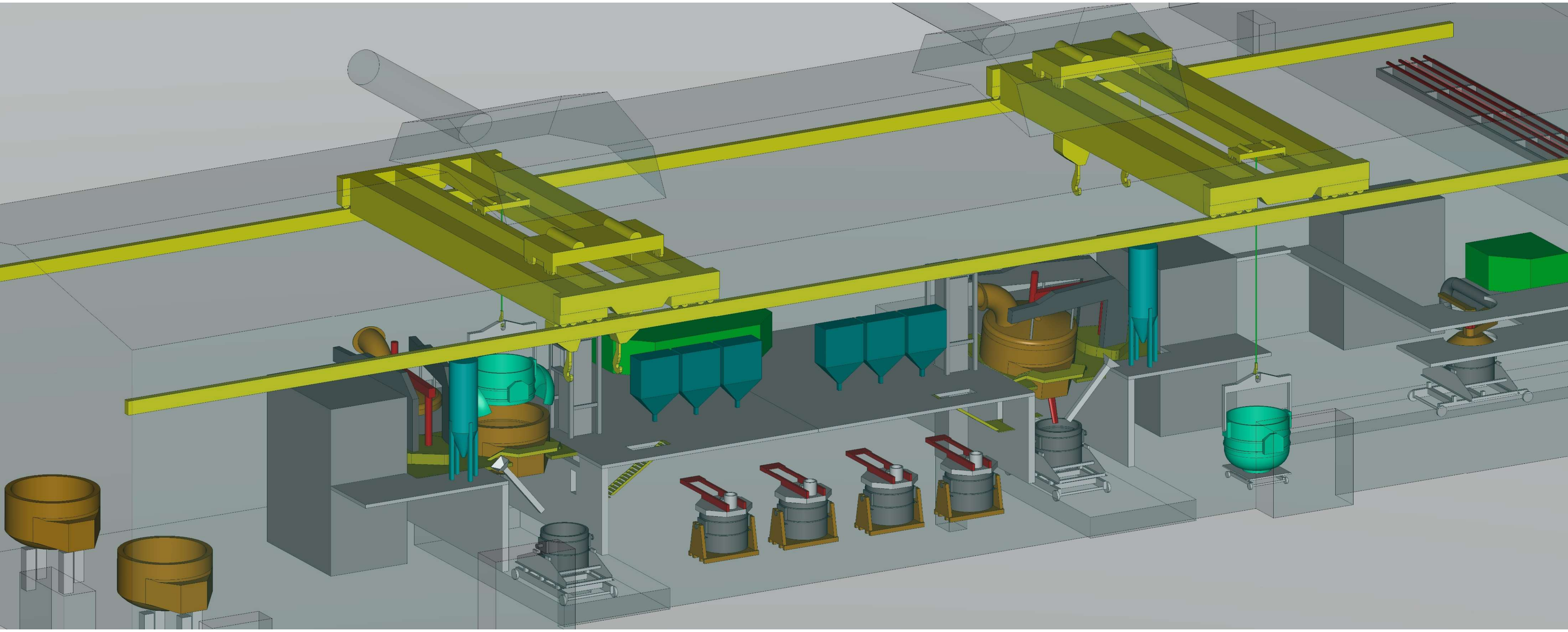
35 ppm	Headache and dizziness after 6-8 hours of exposure
100 ppm	Slight headache within 2-3 hours of exposure
200 ppm	Headache within 2-3 hours of exposure
400 ppm	Frontal headache within 1-2 hours of exposure
800 ppm	Dizziness, nausea, and convulsions within 45 minutes. Insensible within two hours
1600 ppm	Headache, dizziness, and nausea within 20 minutes. Death in less than two hours
3200 ppm	Headache, dizziness and nausea in five to ten minutes. Death within 30 minutes
6400 ppm	Headache and dizziness in one to two minutes. Death in less than 20 minutes
12800 ppm	Death in less than three minutes

Predicting Environmental Hazards

TYPICAL ELECTRIC ARC FURNACE MELT SHOP



TYPICAL ELECTRIC ARC FURNACE MELT SHOP



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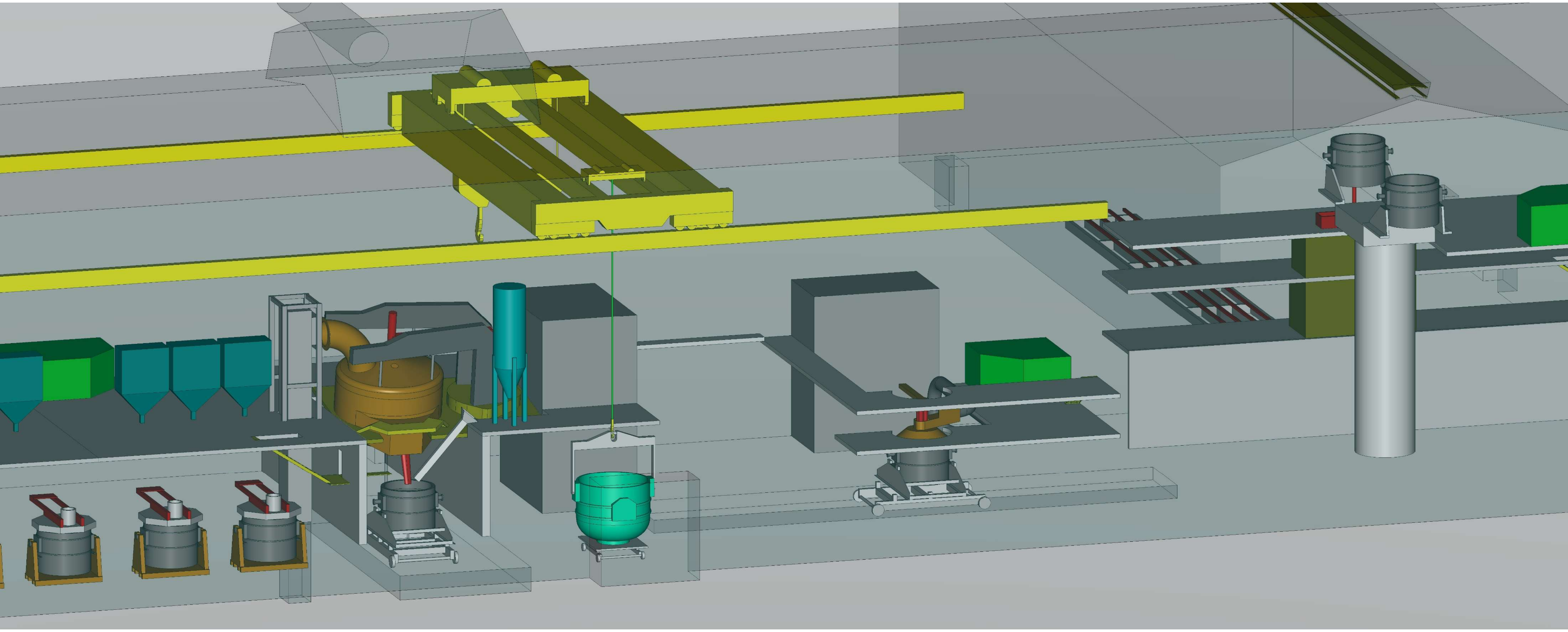

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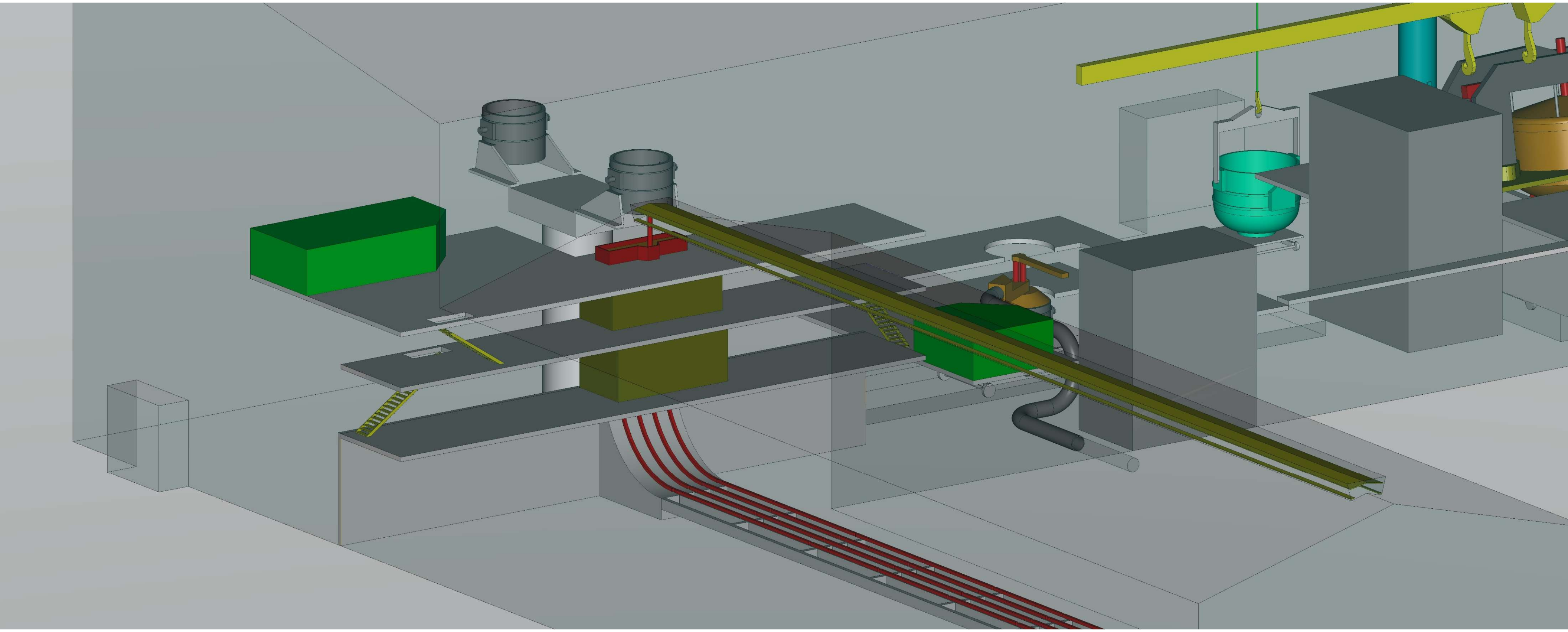


PARTICULATE

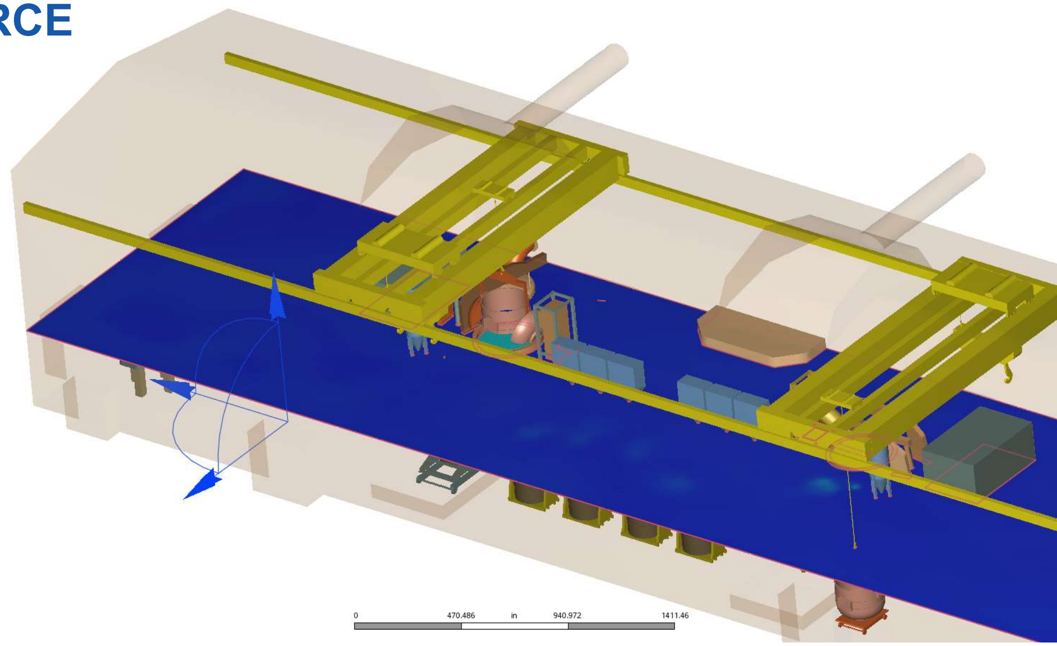
- INCLUDE ALL REQUIRED BOUNDARY CONDITIONS
  - OPEN DOORS / ROOF MONITORS
  - VENTILATION VOLUME
  - TEMPERATURES
  - CROSS WINDS
- ASSIGN THE MESH
- LET THE MODEL RUN AND CONVERGE

PARTICULATE

- **SET UP PARTICLE TRACE ABOVE SOURCE**
  - **ADD A PLANE NORMAL TO THE SOURCE**
  - **INSERT PARTICLES**
  - **CHANGE DENSITY AND DIAMETER**

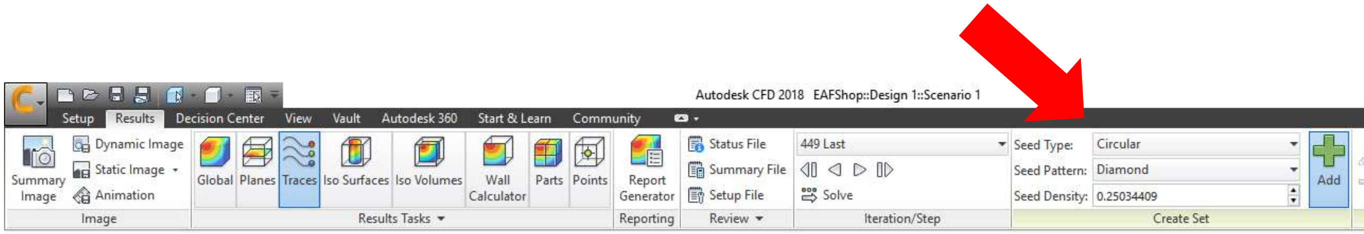
PARTICULATE

- **ADD A PLANE NORMAL TO THE SOURCE**



PARTICULATE

- **SELECT SEED TYPE**

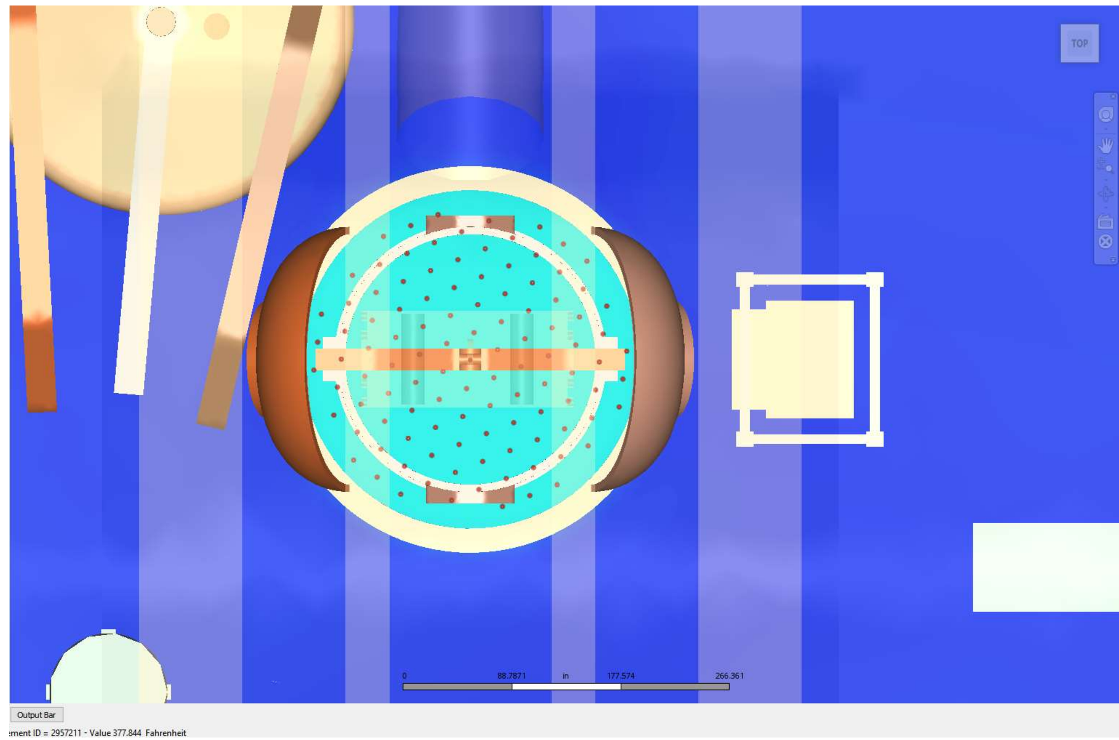


- **SELECT SEED PATTERN**

- **SELECT SEED DENSITY**

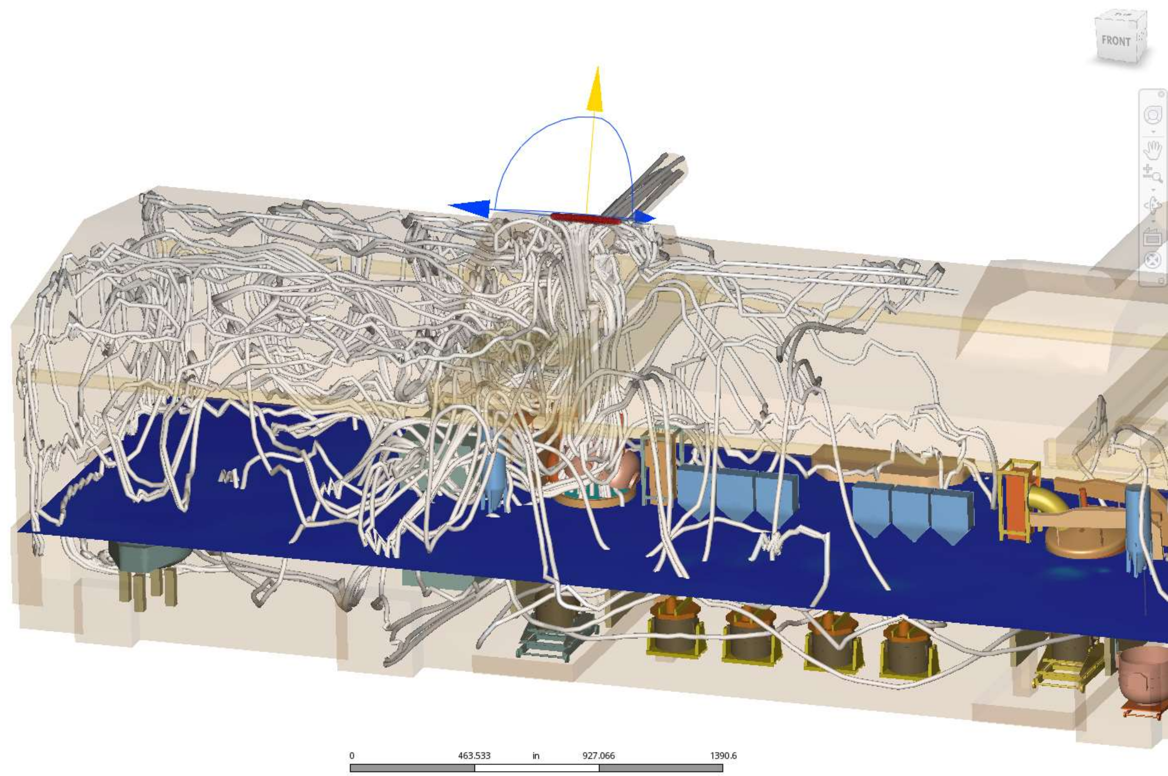
PARTICULATE

- **LEFT CLICK IN THE CENTER OF THE SOURCE**
- **DRAG CURSOR TO INSERT PARTICLES**



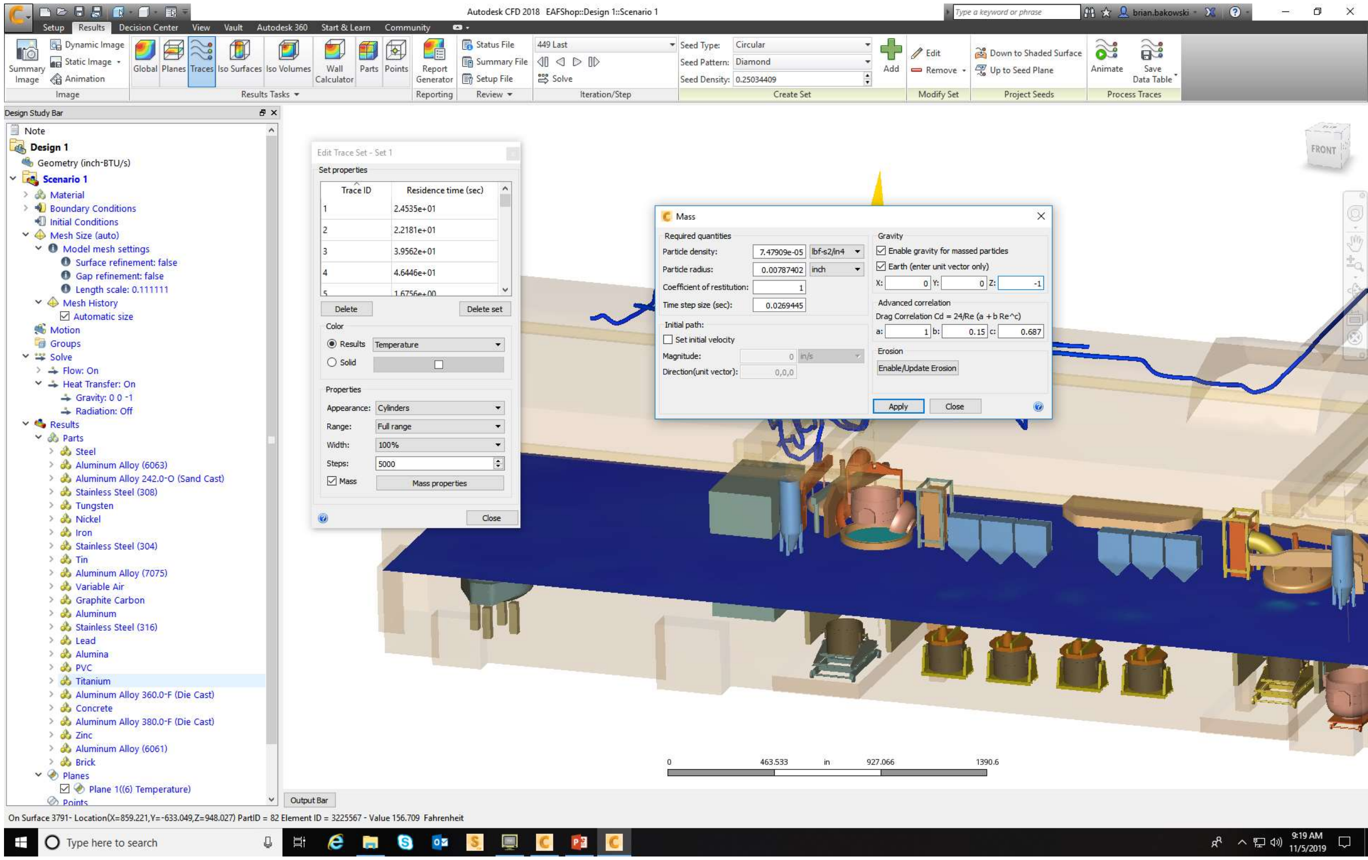
PARTICULATE

- **PARTICLE TRACE WILL APPEAR**



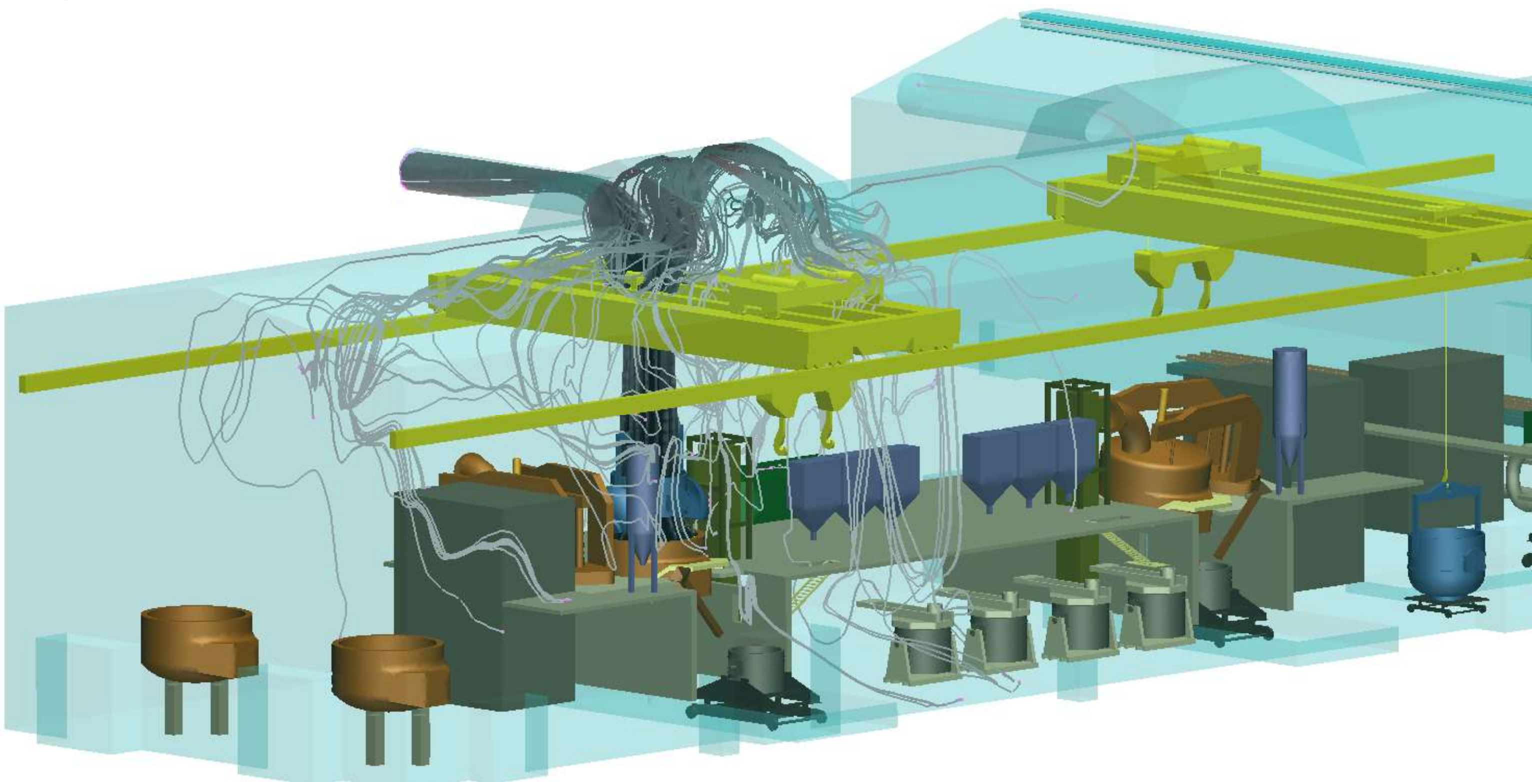
PARTICULATE

- **APPLY MASS AND DENSITY**



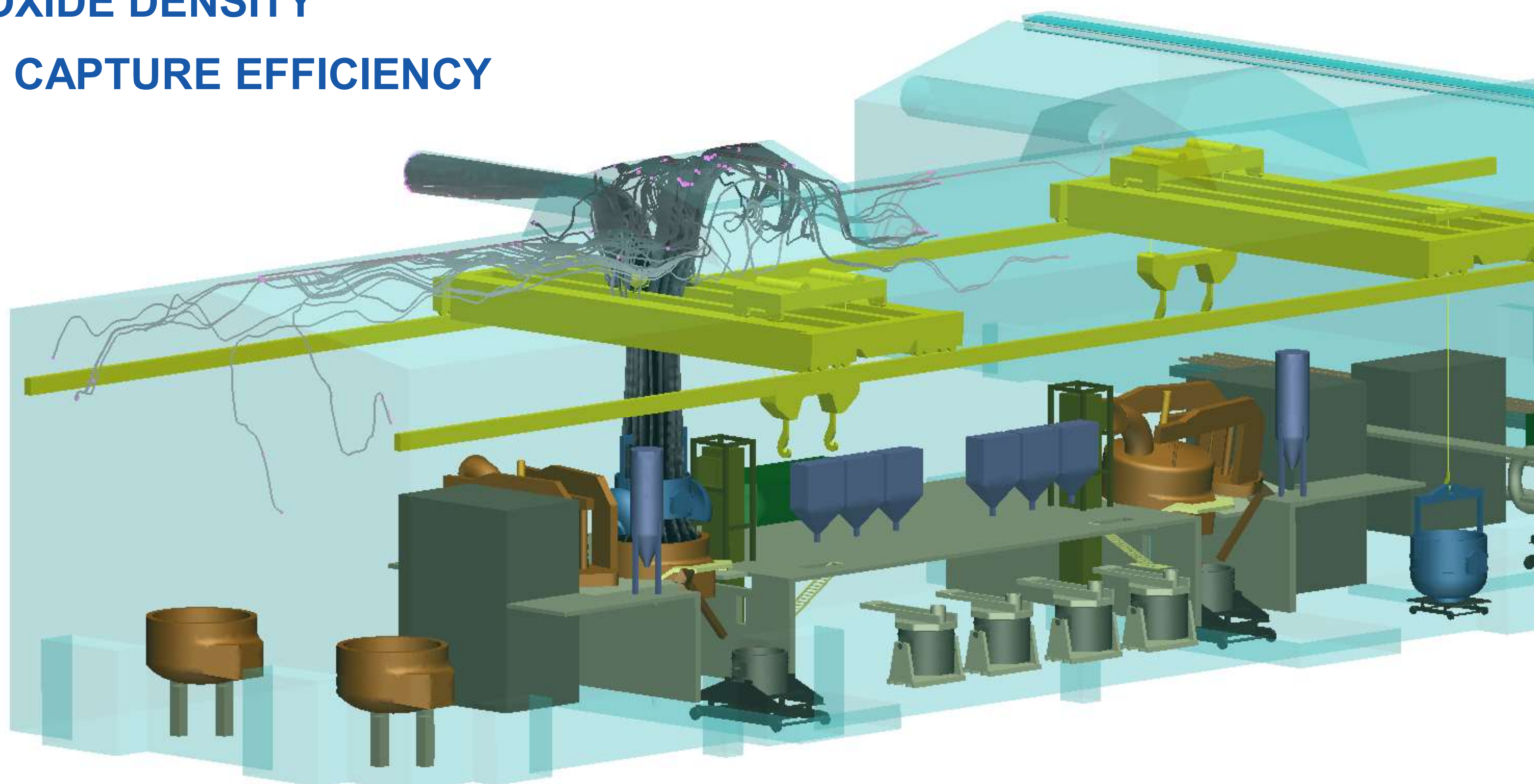
PARTICULATE

- **APPLY LEAD DENSITY**



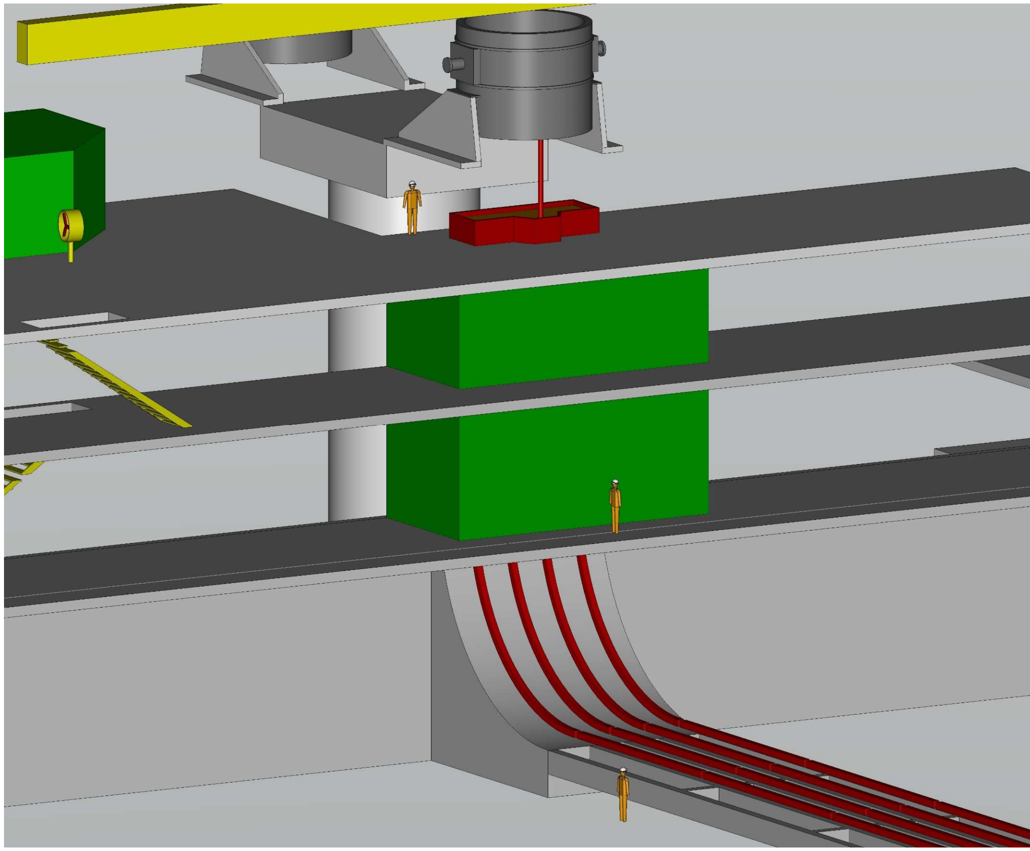
PARTICULATE

- APPLY IRON OXIDE DENSITY
- CALCULATED CAPTURE EFFICIENCY OF 78%



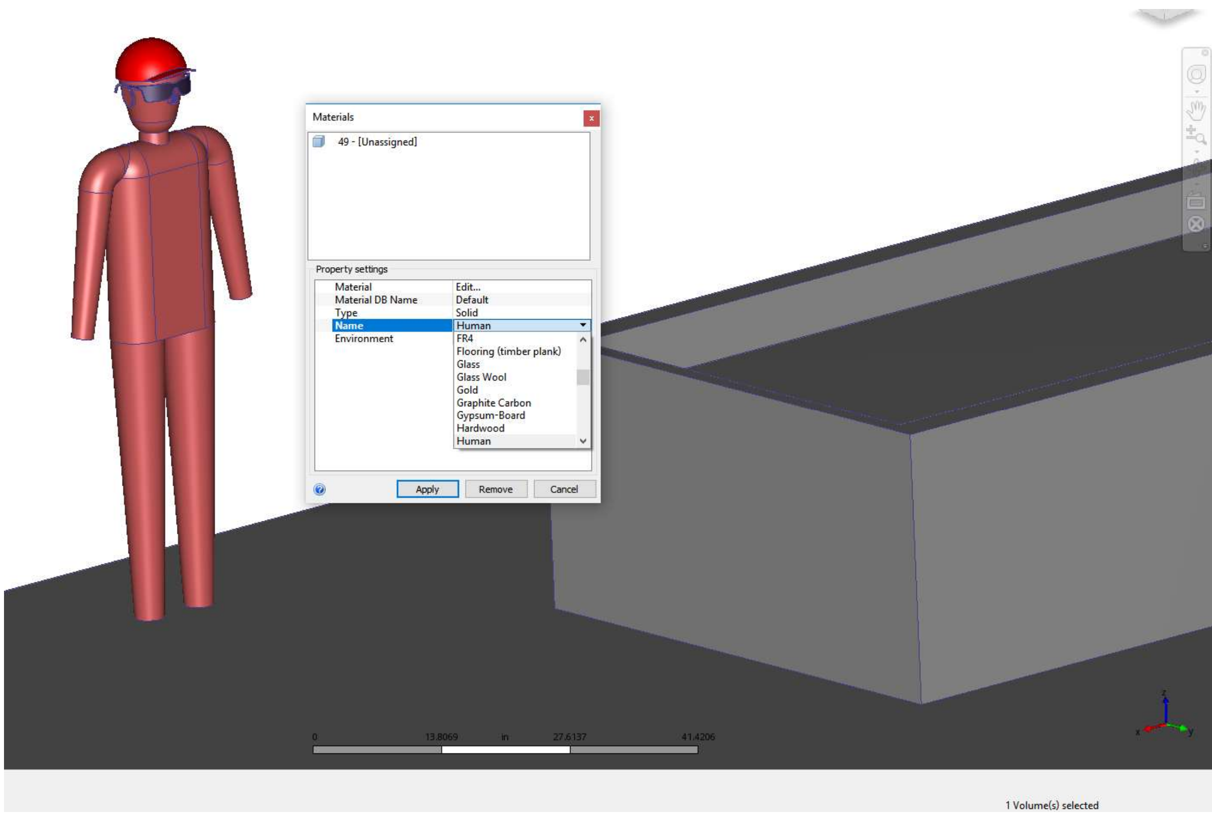
THERMAL STRESS

- SET UP ALL BOUNDARY CONDITIONS
- INCLUDE GEOMETRY FOR A "WORKER"



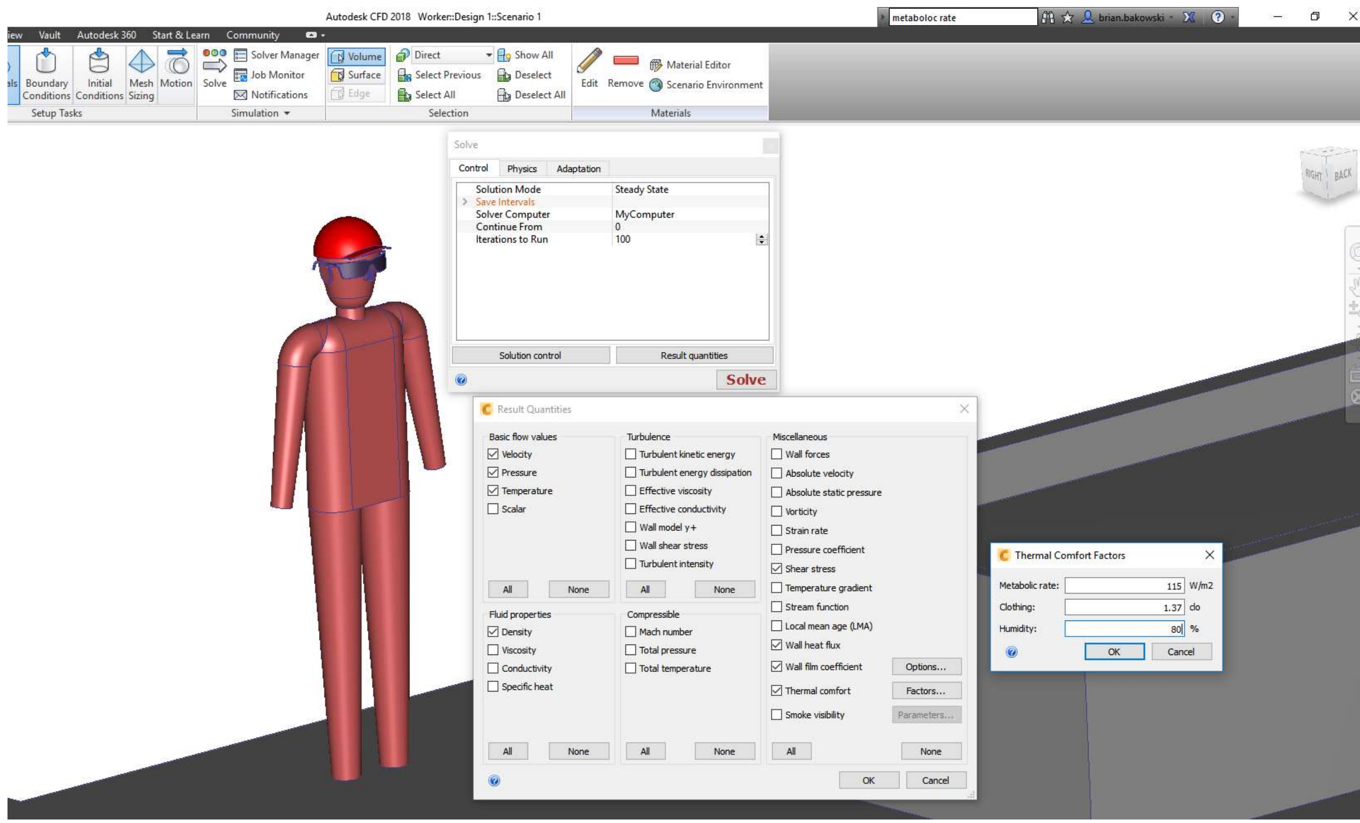
THERMAL STRESS

- **DEFINE WORKER MATERIAL AS "HUMAN"**



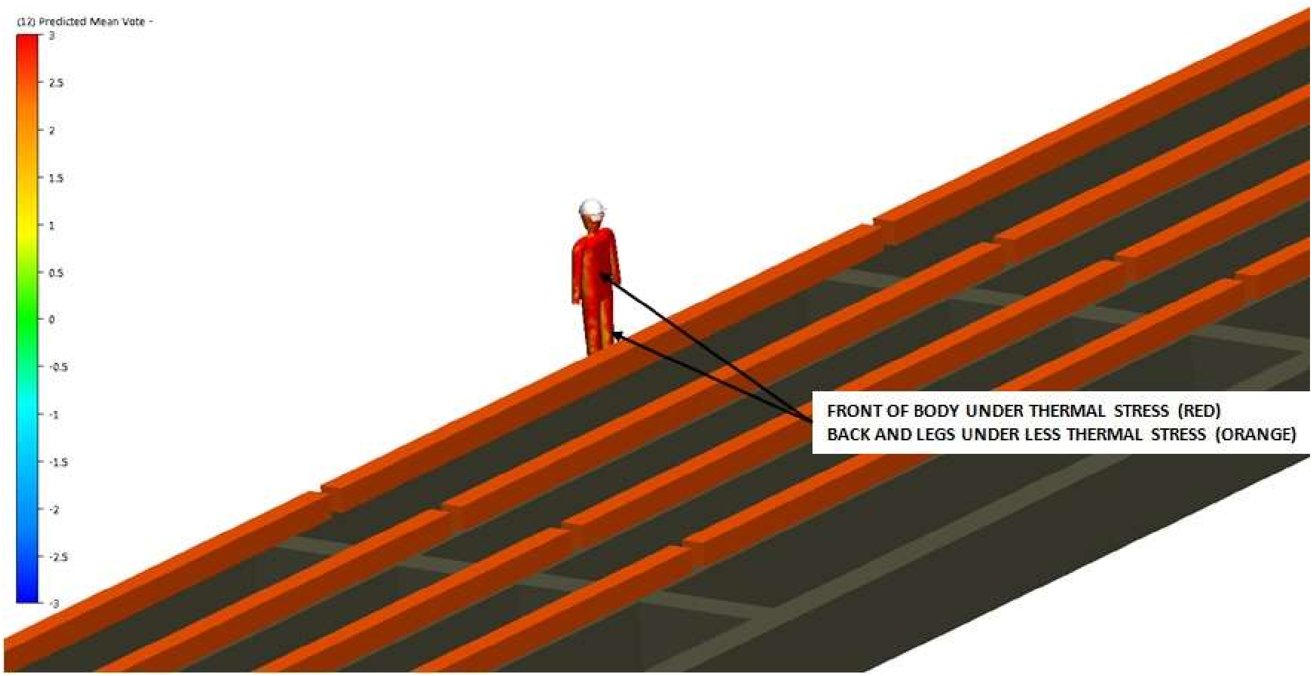
THERMAL STRESS

- **DEFINE METABOLIC RATE**
- **DEFINE CLOTHING FACTOR**
- **DEFINE HUMIDITY**



THERMAL STRESS

- **HUMAN WILL SHOW AREAS OF THERMAL STRESS**
- **SCALE BASED ON PREDICTED MEAN VOTE**

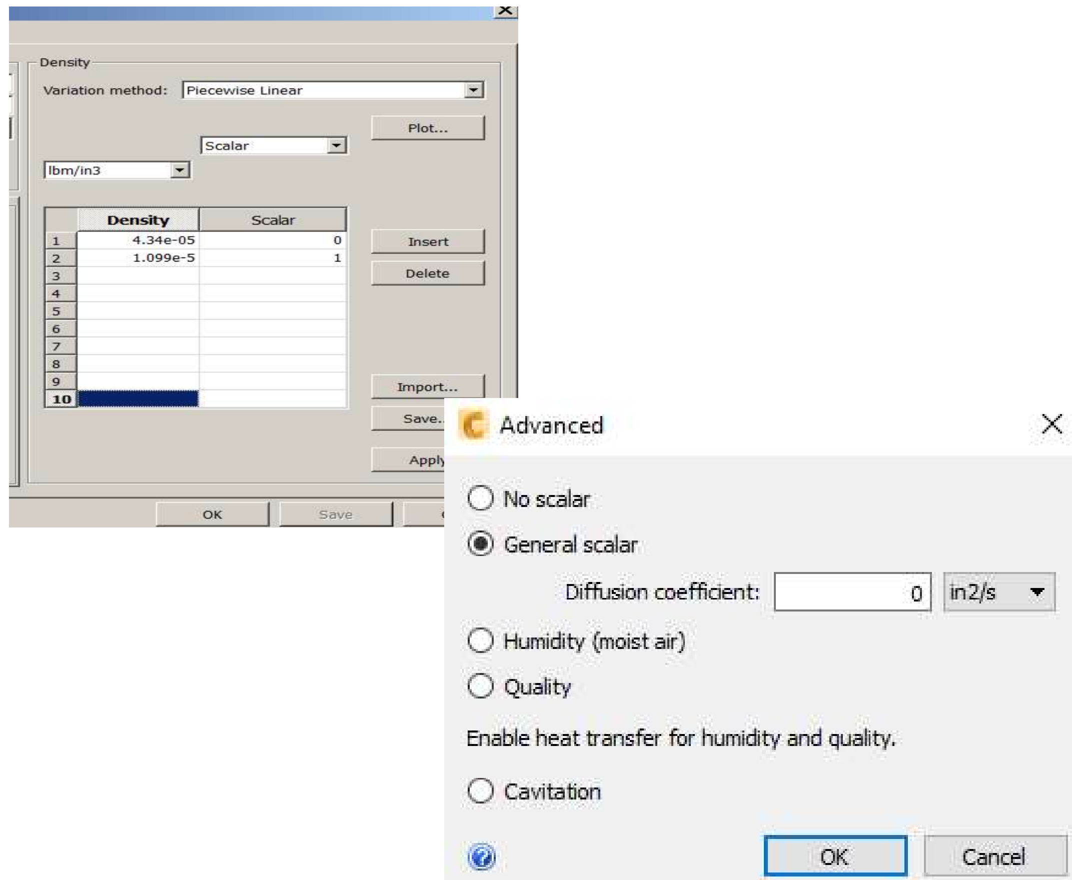


CARBON MONOXIDE

- **INCLUDE ALL REQUIRED BOUNDARY CONDITIONS**
- **ASSIGN A SCALER OF 1 AT THE SOURCE**
- **ASSIGN A SCALER OF 0 AT THE INLETS**

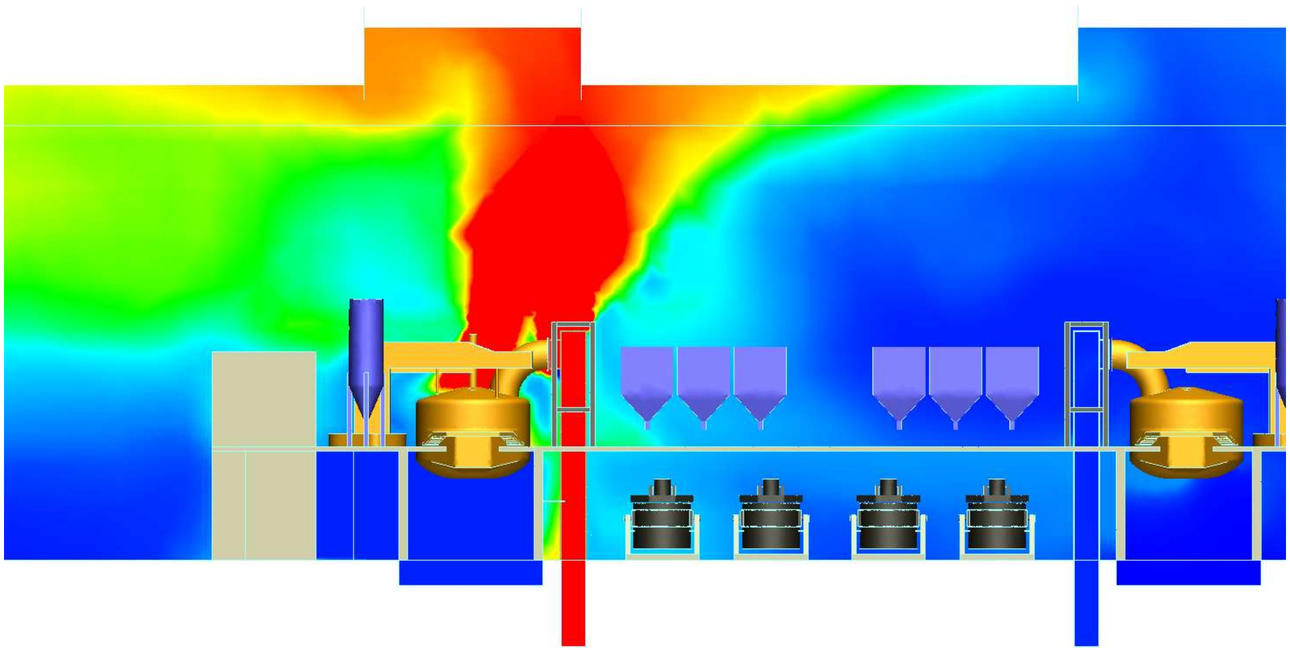
CARBON MONOXIDE

- **SPECIAL ATTENTION TO:**
  - **DENSITY**
  - **DIFFUSION COEFFICIENTS**



CARBON MONOXIDE

- **CO LEVELS CALCULATED IN FURNACE UP TO 6000 PPM**
- **CO LEVELS UPWARDS OF 100 PPM PREDICTED**



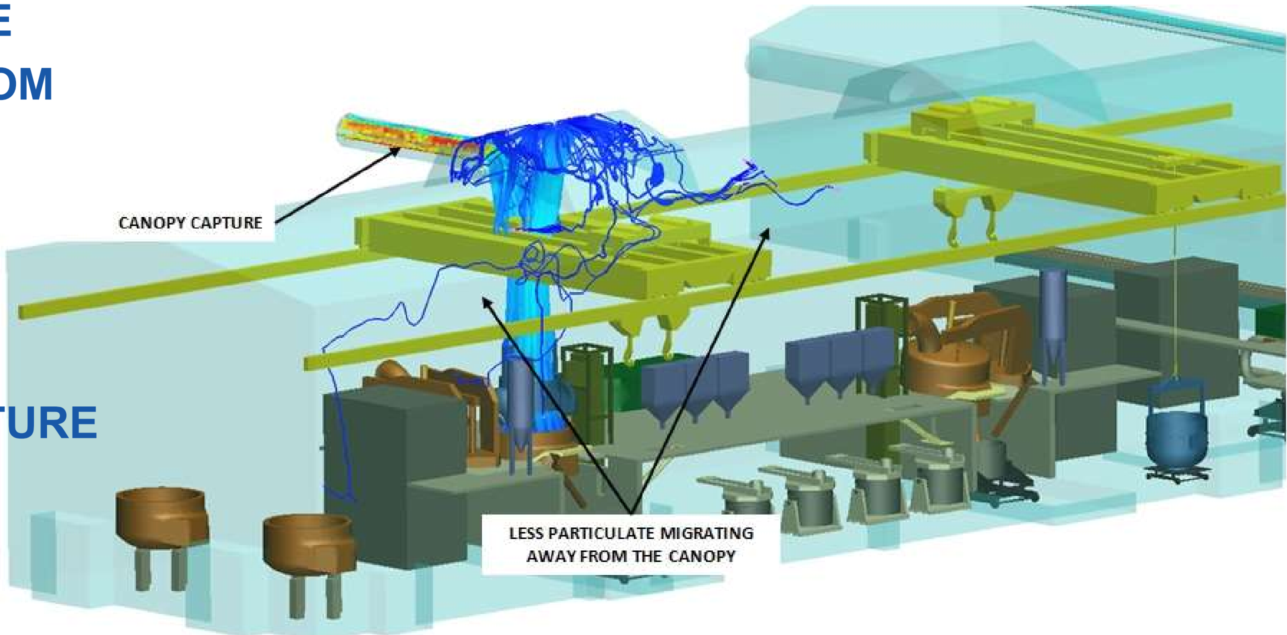
Improving the Work Environment

PARTICULATE

- **IMPROVING CAPTURE EFFICIENCY**
  - **INCREASE VENTILATION**
  - **REDUCE CROSS DRAFTS**

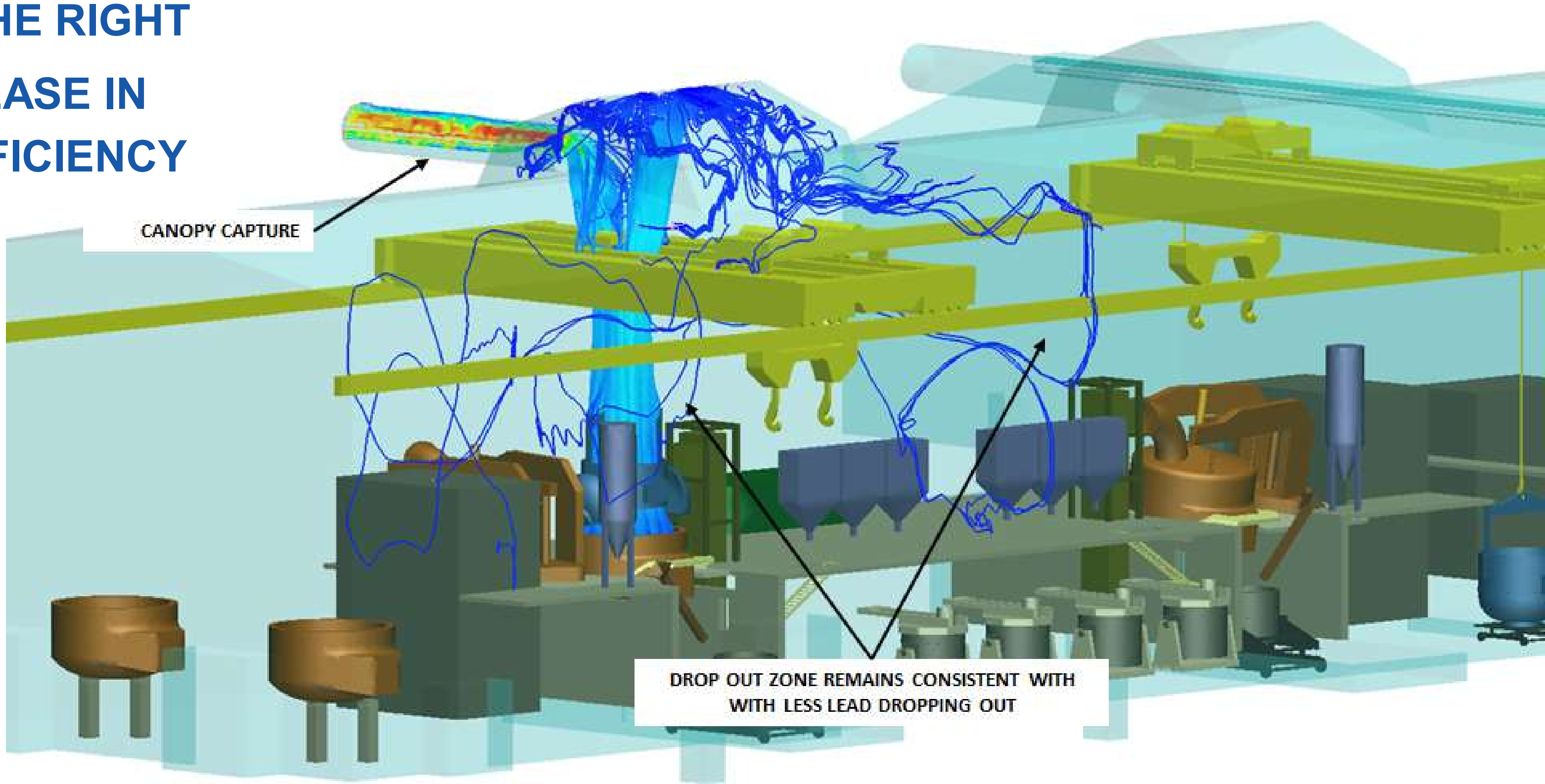
PARTICULATE

- **INCREASING VENTILATION RATE 15% INCREASES THE CAPTURE EFFICIENCY FROM 78% TO 85%**
- **20 MICRON IRON OXIDE PARTICLE SHOWN TO THE RIGHT**
- **CLEAR INCREASE IN CAPTURE EFFICIENCY**



PARTICULATE

- **20 MICRON LEAD PARTICLE SHOWN TO THE RIGHT**
- **CLEAR INCREASE IN CAPTURE EFFICIENCY**



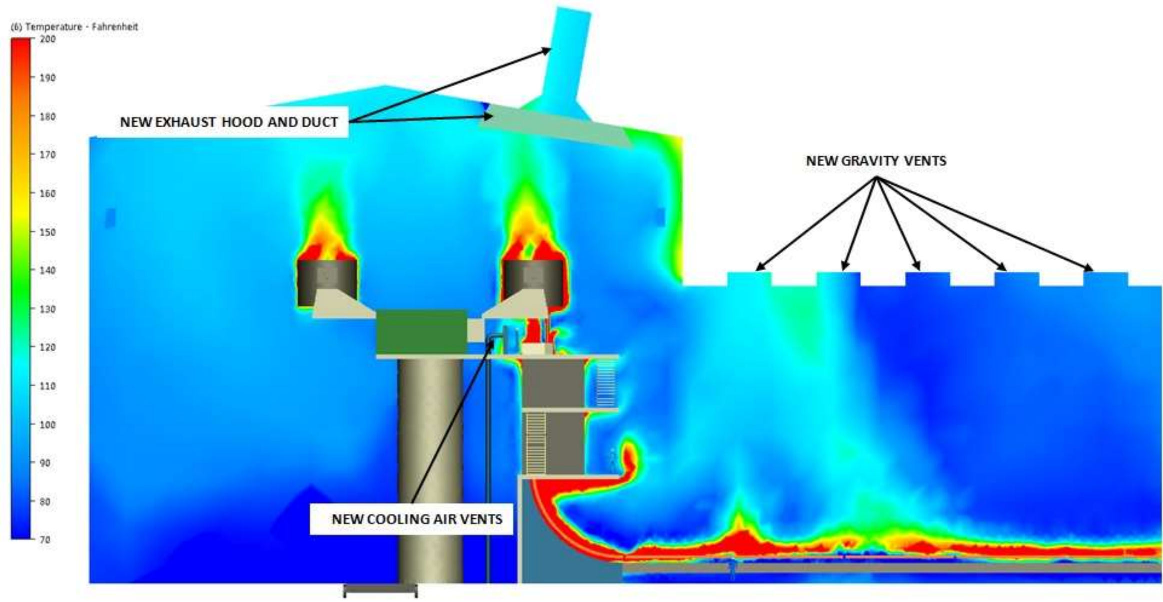
THERMAL STRESS

- **REDUCING THERMAL STRESS**
  - **INCREASED VENTILATION**
    - **POWERED OR NATURAL**
  - **COOL AIR SUPPLY**

THERMAL STRESS

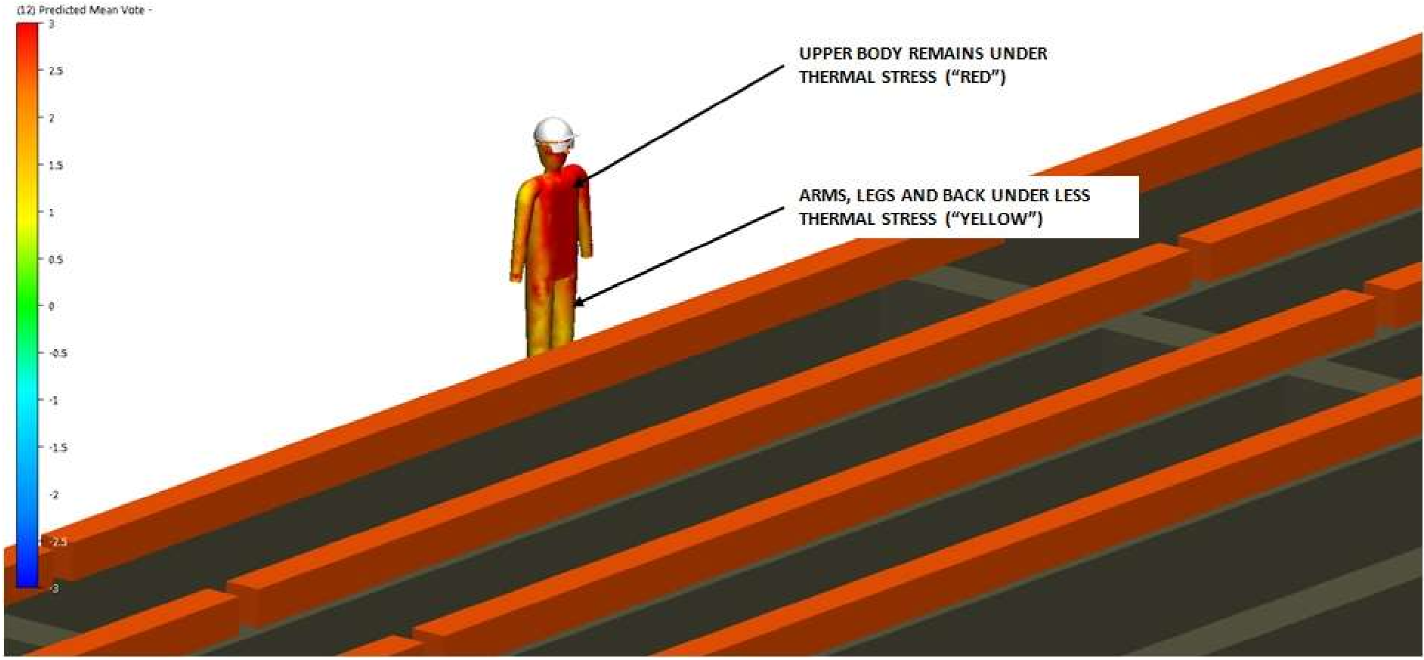
- **ADDING GRAVITY VENTS REDUCES TEMPERATURE THEREFORE REDUCES THERMAL STRESS ON EMPLOYEES**

- **CAUTION - VERIFY THAT THERE ARE NO REGULATIONS THAT RESTRICT ROOF MONITORS**



THERMAL STRESS

- **WORKERS EXPERIENCE LESS THERMAL STRESS**



CARBON MONOXIDE

- **REDUCING CARBON MONOXIDE LEVELS**
  - **COMPLETE COMBUSTION**
  - **INCREASE VENTILATION**
    - **AN INCREASE IN VENTILATION MAY OVER VENTILATE THE PROCESS**

CONCLUSION

- **IDENTIFIED HAZARDS IN AN INDUSTRIAL ENVIRONMENT**
- **LEARNED HOW TO SET UP A CFD MODEL TO PREDICT HAZARDS**
- **IDENTIFIED METHODS TO MITIGATE HAZARDS**
- **COMPARED RESULTS**

THANK YOU FOR ATTENDING

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